

University of Montana

ScholarWorks at University of Montana

Graduate Student Theses, Dissertations, &
Professional Papers

Graduate School

2002

Habitat selection of large flying foxes using radio telemetry : targeting conservation efforts in Subic Bay Philippines

Tammy L. Mildenstein
The University of Montana

Follow this and additional works at: <https://scholarworks.umt.edu/etd>

Let us know how access to this document benefits you.

Recommended Citation

Mildenstein, Tammy L., "Habitat selection of large flying foxes using radio telemetry : targeting conservation efforts in Subic Bay Philippines" (2002). *Graduate Student Theses, Dissertations, & Professional Papers*. 6514.
<https://scholarworks.umt.edu/etd/6514>

This Thesis is brought to you for free and open access by the Graduate School at ScholarWorks at University of Montana. It has been accepted for inclusion in Graduate Student Theses, Dissertations, & Professional Papers by an authorized administrator of ScholarWorks at University of Montana. For more information, please contact scholarworks@mso.umt.edu.



Maureen and Mike
MANSFIELD LIBRARY

The University of

Montana

Permission is granted by the author to reproduce this material in its entirety,
provided that this material is used for scholarly purposes and is properly cited in
published works and reports.

****Please check "Yes" or "No" and provide signature****

Yes, I grant permission

✓

No, I do not grant permission

Author's Signature: Tammy Hildenstein

Date: May 5, 2002

Any copying for commercial purposes or financial gain may be undertaken only
with the author's explicit consent.

HABITAT SELECTION OF LARGE FLYING FOXES USING RADIO TELEMETRY:
TARGETING CONSERVATION EFFORTS IN SUBIC BAY, PHILIPPINES

By

Tammy L. Mildenstein

B.S. Iowa State University, 1991

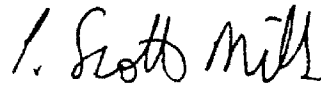
Presented in partial fulfillment of the requirements for the degree of

Master of Science


The University of Montana

2002

Approved by:



Dr. L. Scott Mills, Chairperson



Dean, Graduate School

5-22-02

Date

UMI Number: EP37315

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



UMI EP37315

Published by ProQuest LLC (2013). Copyright in the Dissertation held by the Author.

Microform Edition © ProQuest LLC.

All rights reserved. This work is protected against
unauthorized copying under Title 17, United States Code



ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

Habitat selection of large flying foxes using radio telemetry: Targeting conservation efforts in Subic Bay, Philippines (85 pp.)

Director: Dr. L. Scott Mills

LSM

The Philippines, like many countries in the tropics, confronts underdevelopment, extensive environmental degradation, and lack of commitment to environmental conservation. Since the conservation impact of wildlife research is dependent upon management using the results, it is important to investigate topics that have local value, are relevant to managers, and provide results that can contribute to conservation management efforts. The rare colony of endemic and endangered large flying foxes at Subic Bay is optimal for conservation focus. In addition to being keystone, flagship, and umbrella species, the bats are important to Subic Bay's economy and its indigenous cultures. Habitat selection information streamlines management's efforts to protect and conserve these popular but threatened animals.

We used radio telemetry to describe the bats' nighttime use of habitat on two ecological scales: vegetation and microhabitat. The fruit bats used the entire 14,000 ha study area, including all of Subic Bay Watershed Reserve, as well as neighboring forests just outside the protected area boundaries. Their recorded locations in the study area ranged between 0.4 km and 12 km from the roost. We compared the bats' use to the availability of vegetative habitat types, riparian areas, and bat trees. The fruit bats' locations showed a preference for undisturbed lowland, mangrove, and beach forests and selection against disturbed and agricultural areas. Bat locations also showed selection for fruiting/flowering bat trees, which occurred more often in the bats' locations than expected given availability in the study area. The bats showed strong preference for riparian areas; their locations were in riparian areas over four times more than expected. From these results we recommend that management focus their flying fox conservation efforts on protecting undisturbed forest and, especially, riparian areas.

In addition to providing management with basic ecological background information, our project stimulated fruit bat conservation and environmental awareness in the community. Project related training built the capacity of protected area management and transferred research skills to the wildlife biology students who assisted us. Publicity that the bats got as subjects of conservation research, increased interest in the bats' protection as well as environmental conservation awareness.

TABLE OF CONTENTS

Abstract.....	ii
Table of Contents.....	iii
List of Tables.....	vi
List of Figures.....	vi
Chapter 1: Research topic selection: context and strategy.....	1
Organization of thesis.....	1
Context of thesis research.....	2
U.S. Peace Corps.....	2
Philippine environment.....	4
Study area background (Subic Bay).....	7
National conservation status of fruit bats.....	9
Research focus.....	11
Subic Bay's rare colony of endangered and endemic fruit bats.....	12
Local importance of the fruit bats.....	13
Local threats to the fruit bats.....	14
Paucity of data.....	16
Habitat use research promotes conservation.....	17
Conclusion.....	18
Literature cited.....	20

Chapter 2: Habitat selection of endangered and endemic large flying foxes

in Subic Bay, Philippines.....	26
Abstract.....	26
Introduction.....	26
Study area.....	29
Methods.....	31
Mist netting and capture procedures.....	31
Radio tracking/telemetry.....	32
Habitat selection analysis: Use vs. Availability.....	33
Results.....	37
Mist netting and capturing.....	37
Radio tracking.....	37
Habitat selection analysis: Use vs. Availability.....	38
Effect of telemetry error.....	39
Discussion.....	40
Data limitations and the call for more in-depth study of habitat use.....	44
Implications for conservation management of the fruit bats.....	45
Literature cited.....	49
Appendix A: Endangerment of Old World fruit bats	
by size and endemism to Southeast Asia	66
Appendix B: Mist netting diagram	73
Appendix C: Short life collar design.....	74
Appendix D: Table of captured bats.....	75

Chapter 3: Conservation by-products and recommendations to managers.....	76
Local outreach and environmental education.....	76
Capacity building of local biologists and protected area staff.....	77
Environmental education.....	78
Other data available.....	78
Radio telemetry at the roost.....	78
Observations/hunter interviews.....	80
Recommendation for the conservation management of the Subic Bay large fruit bat colony.....	80
Future research needs.....	82
Acknowledgements.....	84

LIST OF TABLES

Chapter 2

1. Table 1. Identification, use, and availability of tree species used by bats.....57

LIST OF FIGURES

Chapter 2

1. Figure 1. Map of the Philippines with remaining primary forests and Subic Bay.....58
2. Figure 2. Map of the study area with main radio receiver locations.....59
3. Figure 3. Availability and bat use of habitat by vegetation type (pooled data).....60
4. Figure 4. Availability and bat use of habitat by vegetation type (*Acerodon jubatus*)...61
5. Figure 5. Availability and bat use of habitat by vegetation type (*Pteropus vampyrus*).62
6. Figure 6. Availability and bat use of riparian areas (pooled data).....63
7. Figure 7. Availability and bat use of riparian areas (*Acerodon jubatus*).....64
8. Figure 8. Availability and bat use of riparian areas (*Pteropus vampyrus*).....65

Chapter 1: Research topic selection: context and strategy

ORGANIZATION OF THESIS

This M.S. thesis is comprised of three chapters followed by appendices. The first chapter (this chapter) is an introduction to the context in which I conducted my research and the reasoning behind the research focus and objectives. Chapter Two includes research findings written in the form of a manuscript for submission for publication. The third chapter addresses potential implications of the research for the conservation of the forest and the threatened and endangered animals I studied.

My research project, as well as this thesis, has a strong bent towards conservation, stemming primarily from my own personal commitment to promoting environmental conservation. I did my research in the Philippines, a country of extraordinarily high biodiversity, but also an underdeveloped country with great degrees of deforestation, high levels of species endangerment, and very little commitment to conservation. In such a context, I felt obligated to strategically design my research to not only answer an important ecological question, but also to pick a topic that may benefit the study species and the local people by enhancing environmental conservation.

Lastly, I conducted my research in tandem with another research project on the same species of flying foxes. Sam Stier conducted his M.S. research on the dietary choices of the flying foxes, through personal observation, bat hunter interviews, and by collecting fecal matter and identifying the fruit seeds within. While our projects are distinct, they are also complementary, and this afforded a synergism that benefited both projects. Some examples of this synergism are: 1) We helped each other with our field work, 2) hunter interviews that Sam conducted shed light on where I might best receive signals from the

fruit bats I had radio-collared, and 3) radio locations of the fruit bats that I was tracking helped Sam to better understand where the bats were feeding at night and where the seeds in the fecal matter were probably to be coming from. It is likely that parts of Sam Stier's thesis will overlap with mine, especially regarding study area background and the conservation implications of our flying fox research in Subic Bay, Philippines.

CONTEXT OF THESIS RESEARCH

The context in which I conducted my master's thesis research played a significant role in the type of research I did. Specific aspects of this context are my volunteer service in the U.S. Peace Corps, the environmental and conservation status of the Philippines, Subic Bay's history, politics, and unique environment, and the status of fruit bats in the Philippines. These are each discussed in detail below.

U.S. Peace Corps

I did my Master's thesis research during my volunteer service in the U.S. Peace Corps. The Peace Corps' Master's Internationalist Program is a cooperative with the University of Montana that aims to recruit academically focused and trained volunteers for Peace Corps service. The master's student's activities as a Peace Corps volunteer includes basic research, which serves as the academic field component of his/her Master's degree. In design, all parties benefit from this arrangement. The university diversifies its program with graduate students working all over the world. The Peace Corps, as well as the host community, acquires focused volunteers with specific goals and complementary academic agenda. The volunteer/Master's student has an opportunity to do the research required of their Master's degree program in a place that both needs

her/his enthusiasm and expertise and will likely make use of the results of her/his academic research.

U.S. Peace Corps assigned me to the Integrated Protected Areas System (IPAS) program in the Philippines. The specific goals of the IPAS Program were to promote biodiversity conservation through basic research for conservation management, buffer zone community development, alternative livelihood projects, youth development, and environmental education and awareness. As an IPAS volunteer in my assigned site, Subic Bay, I spent a lot of my time promoting environmental education and awareness and building the capacity of local protected area managers. I made numerous presentations and conducted training sessions for school classes on field trips, biology programs at local universities, protected area managers from throughout Southeast Asia, as well as for local protected area office staff. The academic research component of my volunteer service was the basic ecological research of a large colony of endangered and endemic flying foxes found roosting at the Subic forest edge. This research is the main focus of my Master's thesis.

Integral to U.S. Peace Corps volunteer service, is working as a team with coworkers in a local office for environmental protection. This affords capacity building opportunities on several different levels: conservation planning and management, new skills through training in research methods and wildlife monitoring, and experience on conservation focused public educational campaigns. The protected area in which I lived, the Subic Forest Watershed Reserve, had a local government unit in charge of protection of the forest's biodiversity. The staff at the Ecology Center were effectively my counterparts. I worked with them as a team to enhance protection efforts and gather

background information for developing a sound conservation management plan for the forest.

Philippine environment

The Philippine archipelago has a total land area of nearly 300,000 km², about the size of New Mexico, U.S.A. Originally, this area was nearly completely covered with old growth natural forest, but now less than 3% of that original old growth forest is left (Revilla 1987; World Bank 1989; Kummer 1991). Natural forest cover, inclusive of both old growth and secondary growth forests, disappeared slowly through 300 years of Spanish colonialism, from an estimated 90% when the Spanish first arrived in 1521 to an estimated 70% at the turn of the twentieth century when they were defeated by the Americans (Wernstedt & Spencer 1967). In 1945, natural forest cover had dropped to 60% (Myers 1988), 50% in 1950 (see Kummer 1991) and by 1987, the country was left with only about 22% of its area with natural forest cover (Forest Management Bureau 1988; Swedish Space Corporation 1988). Remnant natural forest is now restricted to steep slopes and high elevations and scattered throughout the archipelago as isolated forest patches in a matrix of non-native grassland (see Kummer 1991; also Myers 1988; see Chapter 2, Fig. 1).

Although it may seem intuitive that deforestation and population growth necessarily go hand in hand, Kummer (1991) presents a very clear argument that deforestation in the Philippines was not a direct result of population growth, but rather due to poorly managed, and often corrupt, forestry practices. Kummer (1991) shows that agricultural area, ranching area, and urbanization, often thought of as majors displacers of natural forest, increased only slightly at the time of deforestation, and poverty, which

would go down if deforestation were occurring to the benefit of the populace, actually went up.

It is clear that the relationship between population abundance and the destruction of natural resources is complex and only meaningful when government's management efforts are considered (Kummer 1991). Anthropogenic factors such as uncontrolled pollution and solid waste disposal, and lack of land tenure policies have also contributed to the demise of the Philippines' natural ecosystems, and these are likely to have been magnified by the increasing human population.

The last century was a time of significant population growth in the Philippines. An estimated population size of 27 million in 1960, grew to 48 million in 1980 (population census data from National Economic Development Authority 1987), to over 80 million in 2000 (Central Intelligence Agency 2001). Now, with over 80 million people within the area of a single U.S. state (298 people/km²—one of Asia's highest population densities), and a high population growth rate, which is among the highest in the world (2.03% per year) (Central Intelligence Agency 2001), it is not surprising that given the lack of effective government control, human needs are taking a large toll on natural resources.

To a conservation biologist, what is important about the rapid growths in deforestation and population in the Philippines is how they individually, as well as synergistically, affected the natural environment. During the time the Philippines' natural forests were being depleted at alarming rates, what forests were left behind were being degraded by exposure to people and the increase in pollution, hunting, and small scale timber and non-timber forest product extraction that came with human access and

increased with population growth (Kummer 1991). In this way, logging was the first cause of loss of natural habitat, and then other anthropogenic factors continued the degradation of what remained. Often, secondary forest relicts (leftover from logged-over primary forests), were subsequently destroyed by poor migrants seeking land for subsistence agriculture (Kummer 1991).

Recent conservation attention has been focused on the Philippines because, coupled with a high degree of environmental degradation, the country harbors an uncommonly rich endemic fauna (ICBP 1992; Dinerstein & Wikramanayake 1993; Wildlife Conservation Society of the Philippines 1997). Since the Philippine archipelago has remained fairly isolated (Heaney 1986) and is comprised of over 7000 islands, it follows that it harbors very high rates of biodiversity and endemism. In fact, it exhibits one of the world's highest species richness on a per unit area basis (Heaney 1997), which is often attributed to the fact that it lies right on "Wallace's line", bridging two major biogeographical regions (Oliver & Heaney 1997). Philippine mammalian fauna, for example, currently sums to 180 species with 115 of these (67%) endemic to the archipelago. These numbers, although already among the world's highest, represent minimum counts, as the rate of discovery of new species is higher in the Philippines than anywhere else in the world (Heaney 1997).

The environmental degradation in the Philippines has had obvious negative impacts on native flora and fauna. Nearly one third, at least 52, of the 180 described Philippine mammals are threatened and endangered (Heaney 1997; Wildlife Conservation Society of the Philippines 1997). The most commonly cited cause is habitat loss and, in cases of larger fauna, hunting. Most major international conservation

organizations recognize the Philippines as one of the highest priorities for world conservation concern (Oliver & Heaney 1997). An important first step towards conservation is developing environmental awareness and a social commitment to conservation in local communities, especially in the politicians, businessmen, and elite who play a large role in deciding environmental policy. Then, biologists must develop the baseline biological and ecological information necessary for strategic conservation management of Philippine endangered species and ecosystems. Once this information exists, the challenge will be encouraging the national and local government units in charge of environmental protection to implement and enforce the recommendations of conservation biologists.

Study area background (Subic Bay)

Subic Bay, found in southwest Luzon Island, Philippines (Chapter 2, Fig. 1), was once the site of the largest overseas U.S. Naval Base. This history plays an important role in the area's natural environment, which is both developed and protected because of the base's influence. Using the area as a forested buffer, storage, and training ground, the Navy put roads and munitions bunkers throughout the forest. Despite these interruptions, the overall conservation impact of the Navy's presence in the forest was arguably positive. Ten thousand hectares of old growth dipterocarp forest escaped a century of deforestation which claimed most of the rest of the Philippine's forests. This forest is an unlikely treasure in the Philippines. It is one of the last, large tracts of lowland old growth forest in the country, and is unique in that it is continuous all the way from 1000 meters elevation to sea level including extensive beach and mangrove forests.

Since the U.S. Navy left the country in 1991, the developed part of the old base has been converted into a Duty Free Zone and Industrial Freeport. The Navy's leftover infrastructure of roads, buildings, a local power plant, and communication system, helped attract foreign investment, and Subic Bay Freeport is now the most rapidly developing industrial area in the country. The Freeport, with its unique history, golf course, yacht club, Duty Free shopping, and natural forest and marine areas, is also a popular tourist destination boasting almost seven million tourists a year (SBMA Tourism Department, personal communication).

The forested area of the old base was declared a National Protected Area in 1992 and is managed by the local government, the Subic Bay Metropolitan Authority (SBMA), which has sought to continue the U.S. Navy's protection efforts against fire, illegal logging, and encroachment. However, the SBMA has also initiated and/or permitted development activities that result in the removal of natural forest cover (see Magdaraog 1992).

The SBMA Ecology Center has the responsibility, among other things, to protect the forest. Initially, however, the Ecology Center was missing the most basic ingredients of a conservation management office including: an inventory of their wildlife, a conservation management plan, conservation projects, research projects, and even trained wildlife biologists. For lack of a clear idea of how to pursue the conservation management of the forested area, and because of heavy political pressure coming from the industrial side of Subic Bay, other responsibilities took precedence. The Ecology Center staff spent most of their time evaluating environmental impacts and granting permits to industrial development plans in Subic Bay.

At the time of my arrival in Subic Bay, the SBMA was involved in the development of a comprehensive protected area management plan to coordinate industrial development and the protection of natural areas. With an emphasis on protection of the forest and endangered species, the management plan had a multiple-use mandate and designated zones for strict protection, forest recreation, and industrial development in the former base's territory. Any biological and ecological research on local endangered species would be incorporated into the management plan and hopefully add to an important argument against continued forest destruction and development.

National conservation status of fruit bats

Old World fruit bats are members of the single family (Pteropodidae) in the megachiropteran suborder. Also called flying foxes, these bats are distributed throughout the Old World tropics, from Africa through Asia and in the South Pacific Islands. Over half (55%) of all Old World fruit bats are recognized by the IUCN as threatened and endangered (IUCN 2000). The proportion of threatened bat species is much larger when endemism and size are considered. Sixty-three percent of the fruit bats endemic to Southeast Asia are threatened, and of the large fruit bats endemic to this region (genera *Acerodon*, *Dobsonia*, *Pteropus*), 75% are threatened (compiled using Mickleburgh et al. 1992 and IUCN 2000; see Chapter 2, Appendix A).

In the Philippines, there are currently twenty-five recognized species of fruit bats, of which fifteen (60%) are endemic (Heaney 1991; Heaney et al. 1998). Ten of the Philippine fruit bat species are listed as threatened and endangered (IUCN 2000), and one species, *Dobsonia chapmani*, is thought to be extinct, although possibly recently rediscovered (Pedregosa 2001). Biologists who have done considerable work in the area

suggest that at least eight other fruit bat species are likely to be vulnerable, especially with the continuation of current levels of forest destruction, but these species are not formally classified as such, often due to the lack of adequate and/or current information (Utzurum 1992; Wildlife Conservation Society of the Philippines 1997; Heaney et al. 1998).

There are nine species of large flying foxes (genera *Pteropus* and *Acerodon*) in the Philippines, and all are of conservation concern (Utzurum 1992; Wildlife Conservation Society of the Philippines 1997; IUCN 2000). Four of the five endemic flying foxes are formally listed as threatened (Wildlife Conservation Society of the Philippines 1997; IUCN 2000), and the fifth endemic species has just recently been discovered in a dwindling forested area on a single oceanic island. While it is an obvious candidate for listing as endangered, it is still being described and as of yet has no name (Wildlife Conservation Society of the Philippines 1997; Heaney and Dans, unpublished data). Two of the Philippines' four non-endemic large flying foxes are formally recognized as threatened and endangered (Wildlife Conservation Society of the Philippines 1997; IUCN 2000), and the other two, though unlisted, are also in need of conservation attention. One is an endemic Philippine subspecies that is considered vulnerable (Mickleburgh et al. 1992), and the other has populations that have declined substantially, but it is unknown if listing is warranted (Utzurum 1992; Wildlife Conservation Society of the Philippines 1997).

My research focused on the endangered Philippine Giant Fruit Bat (*Pteropus vampyrus lanensis*) and Golden-Crowned Flying Fox (*Acerodon jubatus*), two of the largest fruit bats in the world (Heaney and Heideman 1987). *Pteropus vampyrus lanensis*

is an endemic subspecific member of a species distributed throughout tropical Asia; the conservation status of the Philippine subspecies is considered vulnerable (Mickleburgh et al. 1992). *Acerodon jubatus* is a species endemic to the Philippines and is endangered (Mickleburgh et al. 1992; Wildlife Conservation Society of the Philippines 1997; IUCN 2000).

RESEARCH FOCUS

There is no question that biological research leading to environmental conservation is needed in the Philippines. In this country of extraordinarily high biodiversity and endemism, there are also great degrees of deforestation, high levels of species endangerment, and very little commitment to conservation. Subic Bay is not only unique but also important for conservation as the last large tract of lowland monsoon forest in the country. Any conservation research in the Subic Bay forest should recognize its rarity and aim to promote the conservation of the forest.

As a solitary wildlife biologist, I could only expect to focus my research activities on one project. It was, therefore, important to carefully and strategically choose a project that would have the biggest potential impact on conservation at Subic Bay. To be effective, the project needed to appeal to the Ecology Center and serve as an impetus for their conservation monitoring and planning efforts. It also needed to appeal to investors and developers, who exert political power over the Ecology Center. Finally, it needed to interest the local community, schools, and tourists, who support the protected area, and who, en masse, have the capability to influence conservation and development in the region.

I focused my research on the habitat use of two large fruit bat species for a number of reasons: 1) The bats are endemic and endangered, and the Subic Bay colony is one of the last roosts of these bats, 2) The large fruit bats are well-known and valued locally by many different sectors of the community, 3) The bats face significant threats in Subic Bay, illegal hunting and habitat loss, both of which could be monitored if more information were available, 4) The ecology of these bats had never been studied, and 5) Habitat use research offers training opportunities for Filipino counterparts. I describe these qualities and how they make the bats an optimal choice for conservation research in more detail below.

Subic Bay's rare colony of endangered and endemic fruit bats

The forest at Subic Bay supports a fruit bat colony with the vulnerable Philippine Giant Fruit Bat (*Pteropus vampyrus lanensis*) (Mickleburgh et al. 1992) and the endangered and endemic Golden-Crowned Flying Fox (*Acerodon jubatus*) (Mickleburgh et al. 1992; IUCN 2000). Our rough estimate of the Subic Bay's flying fox colony size in 1999-2000 was 30,000 individuals (Mildenstein and Stier, unpublished data). Records suggest that this may be about only 1/5 the size of historic colonies (Taylor 1934), but it is now one of the largest colonies remaining in the country (Mickleburgh et al. 1992; Utzurrum 1992). Large sized, mixed colonies of these flying foxes were formerly present on every major island in the Philippines (except in the Palawan region), but they have now disappeared from most of the islands that once supported them (Taylor 1934). Now, only a few colonies over 10,000 individuals are known, including the Subic Bay roost, and the handful of other colonies often number only in the hundreds (Mickleburgh et al. 1992).

Local importance of fruit bats

The flying fox roost of Subic Bay is important as one of the country's last remaining, large colonies of these endemic and endangered fruit bats. While this alone makes them conservation worthy to species-focused scientists, long-term conservation efforts will have to be maintained by the local community. My choice of these bats as my study species was, therefore, equally due to their conservation value to the rare forest and to the local community of Subic Bay.

Ecologically, fruit bats are strong interactors, or ecological “keystones”, as pollinators and seed dispersers and play a key role in forest regeneration (Marshall 1985; Fleming 1988; Cox et al. 1991; Rainey et al. 1995, Richards 1995). Because they are maintainers of the forest, they likely have an indirect economic importance to the Subic Bay area's burgeoning industry, which is totally dependent on the forest for water for its factories; nearly 11 million m³ of water is drawn from Subic's forest per year (Subic Water, personal communication). Also of economic importance, the bats are commonly advertised as one of Subic Bay's unique attractions, which draws foreign investors and tourists to the SBMA area.

Since many of the daily visitors to the bat roost are eco-tourists and students on field trips, the flying foxes serve as flagship species for environmental education and awareness. School groups often visit the Subic Bay bat roost to experience a real life example of the ecology and biology lessons they learn in the classroom. Seeing the bats in their natural habitat is likely one of the only times students and tourists will ever experience a charismatic, living relict of the Philippines' natural heritage. This, in turn,

may generate enthusiasm for learning about nature and support for environmental conservation.

Culturally, the bats are important to indigenous Aeta communities, who regularly use the forest and are traditional bat hunters. Aeta villages depend on the fruit bats as a food source during parts of the year and have traditional beliefs about the health and healing properties of fruit bat meat (Salvador Dimain, personal communication). Recently, indigenous tribes received protection under Philippine law, and the national government has made an effort to set aside land to the tribes for self-government. National interest has grown to learn about and protect the cultural heritage of these indigenous Filipinos.

For decades, non-indigenous hunters have also hunted fruit bats and they, too, show interest in conserving bats. Although bat hunting by non-indigenous Filipinos is illegal, like many of the wildlife laws in underdeveloped countries, this is neither widely publicized nor enforced. Our experience is that because Filipino bat hunters enjoy, and hope to continue to enjoy, their sport hunting, many show interest in fruit bat conservation and claim to be in favor of hunting regulation.

Local threats to fruit bats

Research may help conservation managers mitigate two major threats to the bats: unregulated hunting and habitat loss. As described above, both indigenous and non-indigenous Filipinos hunt fruit bats. The population growth of the bats has not been studied, and it is, therefore, unknown whether bat hunting is sustainable in the long term. Since the Aetas' right to hunt wildlife is legally protected, managers focus their bat conservation efforts on the illegal hunting by non-indigenous hunters. This type of

hunting is difficult to control away from the bat roost, not knowing where the bats go at night, which is when most hunting occurs. Habitat use information could assist managers to identify and target their patrol efforts to limit poaching.

Loss of habitat is a second problem that is difficult to enforce for the same reason: the bats' use of foraging habitat is unknown. Prior to this project, Subic Bay protected area managers were not aware that habitat loss within the forest could harm the bats. Years of observations and/or anecdotes of a sky-full of bats flying far away from the Subic forest in the evenings had led to the assumption that the bats traveled great distances to forage and did not use the forest of Subic Bay at all. As a consequence, it was initially difficult to convince managers that conservation efforts would need to include Subic Bay forests.

The economic and political pressure to develop Subic into an industrial area often leads to disturbance and destruction of the forest. This takes place in various forms (e.g. increased traffic, road widening, enlarging former Navy buildings within the forest, and new industrial developments that displace forest). Furthermore, increase of forest access may contribute to further habitat degradation and hunting, as more industry and traffic also means more people in the forest and more opportunities for illegal hunting and forest destruction. Workers brought into the base welcome the chance to save some money by using local forest products, albeit illegally. On many occasions we witnessed construction workers and guards cutting mangrove trees for cooking fuel, fishing from protected waters, and hunting in the protected forest. This opportunism seems to be more a result of human access to the forest than poverty. Frequently we were told by forest rangers, the

very protectors of the forest, that the forest ranger team of nearly one hundred men eats forest animals (often bats) while on duty.

Paucity of data

Because the U.S. Naval base had protected the Subic forest from hunting and habitat loss, it is home to dozens of threatened and endangered species. Unfortunately, only a few of these endangered species have been studied at all, and none of these studies were on Subic Bay's populations (see Heaney et al. 1987 and Balete et al. 1992). In most of these cases, the endangered species have shown up in the literature on inventory lists. While these provide valuable first time information on these species, inventories offer little which could be used by the Ecology Center for the conservation management of Subic Bay's populations.

I chose to study Subic Bay's fruit bats, because there is very little known about fruit bats in the Philippines in general, and in particular, the Subic Bay large fruit bats, and because basic ecological information is essential to conservation efforts. Work on the biology and ecology of fruit bats in the Philippines is just beginning (population biology: Heideman & Heaney 1989; reproductive biology: Heideman 1987, 1995; feeding ecology: Utzurrum & Heideman 1991; Utzurrum 1984, 1995; Widmann 1996). There are virtually no ecological studies on the Philippines' large flying foxes. What little that has been published about the habitat use of *Acerodon jubatus* and *Pteropus vampyrus lanensis* comes from tangential observations in other studies (Utzurrum 1984; Heaney et al. 1987; Heaney & Heideman 1987; Heideman & Heaney 1989; Utzurrum & Heideman 1991; Widmann 1996), which suggest: 1) *A. jubatus* is closely associated with natural

forest, while *P. vampyrus* has been found both in natural forest and disturbed areas, and
2) Both species tend to travel above the canopy and forage at the canopy level.

Habitat use research promotes conservation

Finally, research on the habitat use of the large flying foxes at Subic Bay may help catalyze active conservation management of these fruit bats and the rare Subic Bay lowland forest. Habitat use information on the bats' nighttime foraging offers an answer to whether the bats use Subic Bay's protected forest, and if so, where. It may also provide protected area managers with detailed information about the bats' nighttime locations, and thereby focus their efforts against hunting and habitat loss/forest destruction. Finally, providing flying fox habitat use information encourages the protected area management planners to take into account the needs of endangered fruit bats.

It is clear that solving the hunting and habitat loss problem is bigger than any legal action, especially since the enforcers, the rangers, are bat hunters, and the government in charge of forest protection supports projects that destroy forest. Habitat use research is also an effective means of training protected area managers about endangered species monitoring and protection. The gathering of habitat use data is relatively straightforward, and the resulting data (e.g. locations on a map) can be readily understood and used by management. Since the SBMA Ecology Center manages Subic Bay forest as an area of zones, the monitoring of fruit bat habitat use locations can be readily incorporated into current management routines.

Also, since the fruit bats are wide-ranging species, they may serve as umbrella species of Subic Bay's forest; protecting their habitat would likely mean protecting much of the Subic Bay Watershed Reserve and beyond (similar sized bats in Australia regularly

fly 20 km away from their roost during nighttime foraging forays (McWilliam 1985-1986; Eby 1991; Spencer et al. 1991; Palmer & Woinarski 1999; Tidemann et al. 1999). The habitats of many other threatened and endangered species within Subic would, therefore, also be protected. Identification of an umbrella species does not lead to forest protection, however, unless that species' habitat, and a commitment to conserving that habitat, is established. Habitat use information and training managers to understand and appreciate the resulting data are prerequisites to promoting conservation of fruit bat habitat, and therefore, conservation of Subic Bay forest in general.

CONCLUSION

The Philippines, like many countries in the tropics, confronts underdevelopment, extensive environmental degradation, and has little commitment to environmental conservation. In addition to lacking basic biological and ecological information about their protected areas, managers often fail to appreciate of the need for conservation, and lack the skills and understanding of how to pursue conservation management. Since the conservation impact of research is dependent upon management using the results, it is important to investigate topics that are relevant to managers and that provide results that can contribute to conservation management efforts. Finally, while many species may be endangered, not all of these species are created equally in the local community's eyes. Studying a species of local importance may foster social and political support for conservation management long after the initial research has been completed.

The colony of large flying foxes as Subic Bay was an obvious choice for research and conservation efforts for all these reasons. The roost is not only one of the last

populations of these endemic and endangered species, but the bats are important to Subic Bay ecologically, economically, educationally, culturally, and are popular with local residents. Studying the fruit bats' habitat use in Subic Bay may help managers to protect these bats from forest habitat destruction and illegal hunting, and offers a capacity building opportunity for the Ecology Center, which would leave them with wildlife monitoring skills and a greater appreciation for wildlife conservation management.

LITERATURE CITED

- Balete, D. S., H. C. Miranda, Jr., L. R. Heaney, and J. F. Rieger. 1992. Diversity and conservation of Philippine land vertebrates: An annotated bibliography. *Silliman Journal* 36(1):129-149.
- Central Intelligence Agency. 2001. *The World Factbook*. Washington, D.C.: Central Intelligence Agency, 2001.
- Cox, P. A., T. Elmqvist, E. D. Pierson, and W. E. Rainey. 1991. Flying foxes as strong interactors in south Pacific island ecosystems: a conservation hypothesis. *Conservation Biology* 5(4): 448-454.
- Dinerstein, E., and E. D. Wikramanayake. 1993. Beyond “hotspots”: how to prioritize investment to conserve biodiversity in the Indo-Pacific region. *Conservation Biology* 7: 53-65.
- Eby, P. 1991. ‘Finger-winged night workers’: managing forests to conserve the role of grey-headed flying foxes as pollinators and seed dispersers. In Lunney, D. ed. *Conservation of Australia’s Forest Fauna*. 91-100. Royal Zoological Society, Mosman, NSW.
- Fleming, T. H. 1988. *The Short-tailed Fruit Bat*. University of Chicago Press.
- Forest Management Bureau. 1988. *National Forest Resources of the Philippines*. Manila: Philippine-German Forest Resources Inventory Project.
- Heaney, L. R. 1986. Biography of mammals in SE Asia: estimates of rates of colonization, extinction and speciation. *Biological Journal of the Linnean Society* 28:127-165.

- Heaney, L. R. 1991. An Analysis of Patterns of Distribution and Species Richness Among Philippine Fruit Bats (Pteropodidae). *Bulletin American Museum of Natural History* 206:145-167.
- Heaney, L. R. 1997. Introduction: Terrestrial Mammals. pp. 117-144. In *Wildlife Conservation Society of the Philippines. Philippine Red Data Book*. Bookmark, Inc. Makati, Philippines.
- Heaney, L. R., and P. D. Heideman. 1987. Philippine fruit bats, endangered and extinct. *Bats* 5:3-5.
- Heaney, L. R., D. S. Balete, M. L. Dolar, A. C. Alcala, A. T. L. Dans, P. C. Gonzales, N. R. Ingle, M. V. Lepiten, W. L. R. Oliver, P. S. Ong, E. A. Rickart, B. R. Tabaranza Jr., and R. C. B. Utzurrum. 1998. A Synopsis of the mammalian fauna of the Philippine Islands. *Fieldiana: Zoology, New Series* 88:1-61.
- Heaney, L. R., P. C. Gonzales, and A. C. Alcala. 1987. An annotated checklist of the taxonomic and conservation status of land mammals in the Philippines. 1987. *Silliman Journal* 34(1-4):32-66.
- Heideman, P. D. 1987. The reproductive ecology of a community of Philippine fruit bats (Pteropodidae, Megachiroptera). Ph.D. Dissertation, University of Michigan, Ann Arbor, Michigan.
- Heideman, P. D. 1995. Synchrony and seasonality of reproduction in tropical bats. *Symposia of the Zoological Society of London*. 67:151-155.
- Heideman, P. D., and L. R. Heaney. 1989. Population biology and estimates of abundance of fruit bats (Pteropodidae) in Philippine submontane rainforest. *Journal of Zoology (London)* 218:565-586.

- ICBP. 1992. Putting biodiversity on the map: priority areas for global conservation. International Council for Bird Preservation, Cambridge, United Kingdom.
- Ingle, N. R., and L. R. Heaney. 1992. A key to the bats of the Philippine islands. Fieldiana Zoology. New Series. No. 69.
- IUCN. 2000. IUCN Red list of threatened species. <www.redlist.org> January 2002. International Union for Conservation of Nature and Natural Resources. Gland, Switzerland.
- Kummer, D. M. 1991. Deforestation in the postwar Philippines. University of Chicago Press. Chicago, Illinois, USA 176pp.
- Magdaraog, G. L. 1992. A strategic defense plan for Subic forest. Unpublished report commissioned by WWF-U.S. in cooperation with the Department of Environment and Natural Resources, Philippines.
- Marshall, A. G. 1985. Old world phytophagous bats (Megachiroptera) and their food plants: a survey. Zoological Journal of the Linnean Society 83: 351-369.
- McWilliam, A. N. 1985-1986. The feeding ecology of *Pteropus* in North-Eastern New South Wales, Australia. Myotis 23-24:201-208.
- Mickleburgh, S. P., A. M. Hutson, and P. A. Racey. 1992. Old World Fruit Bats: An Action Plan for their Conservation. International Union for the Conservation of Nature and Natural Resources Press. Gland, Switzerland.
- Myers, N. 1988. Environmental degradation and some economic consequences in the Philippines. Environmental Conservation 15(3):205-214.
- National Economic Development Authority. 1987. Philippines Statistical Yearbook, 1987. Manila: NEDA. In Kummer 1991.

- Oliver, W. L. R., and L. R. Heaney. 1997. Biodiversity and conservation in the Philippines: An introduction to global priority. pp. xi-xix In Wildlife Conservation Society of the Philippines. Philippine Red Data Book. Bookmark, Inc. Makati, Philippines.
- Palmer, C., and J. C. Z. Woinarski. 1999. Seasonal roosts and foraging movements of the black flying fox (*Pteropus alecto*) in the Northern Territory: resource tracking in a landscape mosaic. *Wildlife Research* 26:823-838.
- Pedregosa, M. dG. 2001. Note on capture of a *Dobsonia* species in Cebu, Philippines. Wildlife Conservation Society of the Philippines Annual Symposia. Silliman University, Dumaguete City, Negros, Philippines. April 2001.
- Rainey, W. E., E. D. Pierson, T. Elmqvist, and P. A. Cox. 1995. The role of flying foxes (Pteropodidae) in oceanic island ecosystems of the Pacific. Pages 47-62 in P.A. Racey and S.M. Swift, eds. Ecology, behaviour, and evolution of bats. Symposia of the Zoological Society of London. Number 67.
- Revilla, A. V. 1987. Policy and program agenda for the forest resources management sub-sector. College of Forestry, University of the Philippines, Los Banos, Philippines. In Myers 1988.
- Richards, G. C. 1995. A review of ecological interactions of fruit bats in Australian ecosystems. Pages 167-184 in P. M. Racey and S. M. Swift, eds. Ecology, behaviour and evolution of bats. Symposia of the Zoological Society of London. Number 67.
- Spencer, H. J., C. Palmer, and K. Parry-Jones. 1991. Movements of fruit bats in eastern Australia, determined by using radio-tracking. *Wildlife Research* 18:463-468.

- Swedish Space Corporation. 1988. Mapping of the Natural Conditions of the Philippines. Solna: Swedish Space Corporation. In Kummer 1991.
- Taylor, E. H. 1934. Philippine land mammals. Monographies of the Bureau of Science, Manila. 30:1-548.
- Tidemann, C. R., M. J. Vardon, R. A. Loughland, and P. J. Brocklehurst. 1999. Dry season camps of flying foxes, *Pteropus* spp., in Kakadu World Heritage Area, north Australia. Journal of Zoology (London) 247:155-163.
- Utzurum, R. C. B. 1984. Fig fruit consumption and seed dispersal by frugivorous bats in the primary tropical rainforest of Lake Balinsasayao, Negros Oriental, Philippines. M.S. Thesis, Silliman University, Dumaguete City. 109pp.
- Utzurum, R. C. B. 1992. Conservation Status of Philippine Fruit Bats. Silliman Journal 36(1):27-45.
- Utzurum, R. C. B. 1995. Feeding ecology of Philippine fruit bats: patterns of resource use and seed dispersal. Symposia of the Zoological Society of London. 67:63-77.
- Utzurum, R. C. B., and P. D. Heideman. 1991. Differential ingestion of viable vs. nonviable *Ficus* seeds by fruit bats. Biotropica 23(3): 311-312
- Wernstedt, F. L., and J. E. Spencer. 1967. The Philippine Island World. Berkeley: University of California Press. In Kummer 1991.
- Widmann, P. 1996. Importance of fruit bats for pollination and seed dispersal in orchards and forests in Leyte, Philippines. Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) GmbH, Postfach 5180, D-65726 Eschborn.

Wildlife Conservation Society of the Philippines. 1997. Philippine Red Data Book.
Bookmark, Inc. Makati, Philippines. 240 pp.

World Bank. 1989. Philippines: Environment and National Resources Management
Study. Washington, D.C.: World Bank. In Kummer 1991.

Chapter 2: Habitat selection of endangered and endemic large flying foxes in Subic Bay, Philippines

Abstract: Large flying foxes in insular Southeast Asia are the most threatened of the Old World fruit bats due to high levels of deforestation and hunting, and effectively little local conservation commitment. There have been only a few studies on these bats that provide information useful to their conservation management. The forest at Subic Bay, Philippines, supports a rare, large colony of vulnerable Philippine Giant Fruit Bats (*Pteropus vampyrus lanensis*) and endangered and endemic Golden-Crowned Flying Foxes (*Acerodon jubatus*). These large flying foxes are optimal for conservation focus, because in addition to being keystone, flagship, and umbrella species, the bats are important to Subic Bay's economy and its indigenous cultures. Habitat selection information streamlines management's efforts to protect and conserve these popular but threatened animals. We used radio telemetry to describe the bats' nighttime use of habitat on two ecological scales: vegetation and microhabitat. The fruit bats used the entire 14,000 ha study area, including all of Subic Bay Watershed Reserve, as well as neighboring forests just outside the protected area boundaries. Their recorded locations in the study area ranged between 0.4 km and 12 km from the roost. We compared the bats' use to the availability of vegetative habitat types, riparian areas, and bat trees. The fruit bats' locations showed a preference for undisturbed lowland, mangrove, and beach forests and selection against disturbed and agricultural areas. Bat locations also showed selection for fruiting/flowering bat trees, which occurred more often in the bats' locations than expected given availability in the study area. The bats showed strong preference for riparian areas; their locations were in riparian areas over four times more than expected. From these results we recommend that management focus their flying fox conservation efforts on protecting undisturbed forest and, especially, riparian areas.

INTRODUCTION

Although flying foxes (Old World fruit bats, Pteropodidae) have experienced nearly two decades of international conservation attention, populations are still declining (Mickleburgh et al. 1992; Kunz & Pierson 1994; Tidemann et al. 1999). Large flying foxes (genera with max. forearm length > 110mm) in particular are of concern, because they tend to forage over wide ranges, roost conspicuously in colonies, and are heavily hunted (Pierson & Rainey 1992; Mickleburgh et al. 1992; Kunz & Pierson 1994). Most large flying fox research has taken place in Australia (e.g. reproduction biology: Martin et al. 1995; Vardon & Tidemann 1998; feeding ecology: Richards 1995; Eby 1998;

movements: Eby 1991; Augee & Ford 1999; roost choices: Tidemann et al. 1999). In Southeast Asia, where half (83/166) the world's flying fox species are found, flying foxes remain virtually unstudied (compiled from Mickleburgh 1992; see Appendix A). This is a region with widespread fruit bat hunting (Mickleburgh et al. 1992, and cites therein), the world's highest amount of natural habitat loss (Whitmore 1997), and where there is, effectively, no formal bat conservation commitment from governments (Mickleburgh et al. 1992). A daunting three quarters (20/27) of Southeast Asia's endemic large flying foxes are threatened and endangered (compiled from Mickleburgh et al. 1992, Wildlife Conservation Society of the Philippines 1997, and IUCN 2000; see Appendix A).

Habitat use is an effective place to start conservation ecological research in Southeast Asia, because it provides protected area offices with information conducive to local management style. These offices often focus on their jurisdiction as geographical phenomena and have protected area management plans that are delineated by zones on a map. Areas of special interest such as endangered species' habitats can be easily addressed, understood, and incorporated into management plans and monitoring routines.

Unfortunately, there is little known about the habitat use of large flying foxes. Most studies either infer habitat use from where bats were observed and/or caught (Heideman & Heaney 1989; Widmann 1996) or focus on habitat at roost sites and the surrounding vegetation (Eby 1991; Palmer & Woinarski 1999; Brooke et al. 2000; Vardon et al. 2001). In some cases, foraging habitat use on a local scale has been inferred from observations (Widmann 1996; Brooke et al. 2000; Palmer et al. 2000).

Radio telemetry has proved useful in habitat use studies of smaller flying foxes (Marimuthu et al. 1998; Winkelmann et al. 2000; Reiter & Curio in press), because it

allows for remote sampling of individuals' locations. This technology has rarely been used on large flying foxes. They are difficult to capture, since they often fly above the canopy and well above mist nets (Mudar & Allen 1986; Heideman & Heaney 1989; Ingle 1992; Widmann 1996; Walton & Trowbridge 2000), and they are difficult to track (especially in mountainous terrain), since they fly long distances (Walton & Trowbridge 2000; Brooke 2001). Only a few studies have used radio telemetry to follow the nighttime movements of large flying foxes (lekking behavior of *Hypsignathus monstrosus*: Bradbury 1977; movements of released captive-reared *Pteropus poliocephalus*: Augee & Ford 1999; foraging ecology of *Pteropus alecto*: Palmer et al. 2000; movements of two *Pteropus giganteus* individuals: Walton & Trowbridge 2000; and home range of two *Pteropus samoensis* individuals: Brooke 2001). Radio telemetry has never been used on large flying foxes in Southeast Asia.

At Subic Bay, Philippines, the protected area management office has been developing a conservation strategy for their roost of endangered large fruit bats, *Pteropus vampyrus lanensis* and *Acerodon jubatus*. This colony is particularly important, because it is one of only a few large colonies remaining of the Philippine endemic, *Acerodon jubatus*. Not only are these bats important to Subic Bay ecologically, as pollinators and seed dispersers (Cox et al. 1991) and as an umbrella species for the whole protected area (Chapter 1), but they are popular with the local community, who value them economically for eco-tourism, culturally as traditional food for indigenous Aetas, and as a flagship species for environmental awareness and conservation (Chapter 1). Subic Bay's protected area management office has both the means (e.g. a large, well-educated staff, political status, and a relatively significant amount of funding) and the desire to actively

pursue fruit bat conservation, but they lack the biological and ecological information needed to develop a conservation management plan for the bats. Since no ecological studies with any direct implications for conservation management exist on *Acerodon jubatus*, and only one on *Pteropus vampyrus lanensis* (Widmann 1996), the local government did not know how to protect their endangered bats beyond merely protecting where the bats roosted.

We assisted the protected area management's conservation efforts with habitat use information derived from radio telemetry. We focused our research specifically on the bats' use of the protected area within the boundaries of Subic Bay National Watershed Reserve, where the bats roost and are formally protected from hunting. Our objectives were to describe the bats' use of habitat on two ecological scales: vegetation and microhabitat. We aimed to provide management with a map of areas within Subic Bay used by fruit bats and describe patterns of usage in terms of general vegetative types and microhabitat features, from which a habitat suitability model may be inferred.

STUDY AREA

The study area is a lowland monsoon dipterocarp forest in the Subic Bay Freeport Zone, Southwestern Luzon Island, Philippines (14 47' N., 120 17' E.) (Fig. 1). The Subic Bay Freeport Zone is the former site of the once largest overseas U.S. Naval Base, which occupied the area from 1898 until 1991. The roads and buildings comprising the base are surrounded by a 10,000 ha forest relict, which once served as a buffer zone, storage area, and training grounds for the Navy. This area is now a national protected area of the Philippine government called Subic Forest Watershed Reserve. It lies between Subic Bay

and the Bataan mountains and ranges in elevation between sea level and 1253 meters, with the majority of the forest below 394 meters. The topography is interrupted by several steep volcanic plugs (the highest of these being 486 meters high), which create very hilly terrain.

The climate of Subic Bay is affected by southeastern monsoons causing pronounced wet and dry seasons. Annual rainfall is reported as 3,582 mm, based on a 41-year average by PAGASA Weather Station (Dalmacio & Fernando 2000), with 95% of the rainfall between May and October. An average of five typhoons pass through Subic every three years. Average daily temperature is 26 to 27 degrees Celsius.

The study area is a catchment of six rivers and consists of undisturbed old growth dipterocarp forest, mangrove forest, strand (beach) forest, selectively logged dipterocarp forest, and disturbed/secondary forest next to U.S. Navy installations (e.g. roads, bunkers, and buildings). There is also some residential use of the study area both by the indigenous, forest dwelling, Aeta tribe and by prominent members of the Subic Bay community (e.g. investors, politicians, and government officials) in the neighborhoods created by the Navy to house officers and sailors with families. These residential areas are surrounded by natural forest, but have also led to the introduction of ornamental trees and agricultural varieties. The largest agricultural developments in the forest are a mango orchard (c. 100 ha), an ironwood tree plantation (c. 20 ha), and about 30 hectares of mixed fruit orchards surrounding the Aeta village.

METHODS

We conducted the radio telemetry study from January 2000 to May 2001, with the majority of the radio telemetry locations recorded between May and October, 2000.

Mist netting and capture procedures

To capture the fruit bats, we used three mist-netting sites: one located within the bat roost itself, and the other two adjacent to, but outside of, the roost. Using tree climbers and/or slingshots, we hung ropes over upper canopy tree branches, about 30 to 35 meters high in two trees about 10 to 15 meters apart at each mist-netting site (Appendix B). We used these ropes to raise the mist nets (four black nylon 6m x 3m mist nets sewn together to form a large, 6m x 12m mist net wall) up into the canopy with the top edge at a height of about 28 to 33 meters. We raised the mist nets in the early morning, 2 a.m. to 5 a.m., as the bats were returning to the roost. Once the nets were raised we monitored them continuously. As soon as a fruit bat was captured, we immediately lowered the mist nets and removed the bat to prevent injury.

We identified the species, sex, and age category (pups, juvenile, and adult) as well as measured the weight and forearm length of all captured bats. To each bat over 300 grams, we attached a twelve-gram radio-transmitting collar (Holohil Inc., Ontario, Canada) with a position indicator mechanism, that varied the rate of the signal pulse depending on the orientation of the fruit bat. Vertical transmitters on hanging bats produced a slow, one pulse per second signal; horizontal transmitters (i.e. when the bat was flying) emitted a two pulse per second signal. Cotton collars were substituted for the stainless steel wire collars sent by the transmitter manufacturer to ensure that the collars would be likely to fall off (see Appendix C for collar design), hopefully after the one-year

lifespan of the transmitter battery. Using a syringe as a bottle, we offered sugar water to bats to boost their energy before release. The total time of bat handling from mist net capture to release was about 25 minutes.

Radio tracking/telemetry

Two days after collaring the bats, we began tracking them at night in the field via foot, bicycle, and vehicle. We recorded directions of the bats' flight paths as well as their locations and attempted to visually locate the bats whenever possible.

We also recorded bat locations remotely using triangulation of signal bearings. With two receiver teams on the tops of two of the highest peaks in the area (primarily: Hill 394, (394m); Mt. Sta Rita, (487m); or Mt. Natib, (1253m); see Fig. 2) we simultaneously sampled the bats' signal bearings at ten-minute intervals regularly throughout the night, from around 6:00 pm until 6:30 am. The systematic sampling led to the reading of the signal bearing and location of any individual bat about once every two hours.

In addition to recording the signal bearings, receiver teams recorded whether the bats were hanging or flying, and both the general direction of as well as the observed strength of the received signal. This served as a check to be compared to the resulting triangulated locations of the bats. Of all the triangulated locations, we selected a subset to use in our habitat analysis based on the following criteria: bats in hanging position; bearings with an acute angle between them equal to or greater than thirty degrees; consistency between observer notes on general direction and signal strength compared to the resulting triangulated location.

We tested error on 25 transmitters in known locations using the same methods and radio reception sites used to triangulate the foraging bat locations. In 24 of the telemetry test occasions, those being tested were “blind” to the test (they did not know they were being tested), thereby providing a more direct evaluation of the telemetry error than if the tests were known (Mills & Knowlton 1989). We recorded error as the distance (m) between actual locations of transmitters and locations derived from triangulation of two signal bearings. While all of our bat locations were results of two triangulated bearings, we only had single bearings for some of the error test locations. In the cases where only one bearing was available, we measured error as the distance between the actual transmitter location and the closest point on the signal bearing line.

Habitat selection analysis: Use vs. Availability

We studied the bats’ use of habitat on two different scales: broad-scale vegetative habitat types and two microhabitat features (i.e. riparian areas and specific tree species). We determined selection of habitat by comparing the bats’ use to the availability of habitat types and microhabitat features. For all analyses, bat use was based on triangulated bat locations, which we visited in the field using global positioning system units (Garmin 12XL) and topographical maps of the area (Maps 7072 I and 7072 II, DENR, National Mapping and Resource Information Agency, Makati City, Philippines).

Many habitat use studies define habitat availability as the proportion of each habitat type within the home range of the study species (White & Garrott 2000). For our study, however, it was necessary to define the availability of habitats as the proportions of each habitat type in the study area. Home range sizes of the study species are not known, but similarly-sized fruit bats fly an average of 20 km (McWilliam 1985-1986;

Eby 1991; Spencer et al. 1991; Palmer & Woinarski 1999; Tidemann et al. 1999) and a maximum of 50 km (Eby 1991) away from their roosts during nighttime foraging forays. This distance covers the Subic Bay protected area and much of neighboring provinces as well. With the limitations of our radio telemetry sampling equipment, topography, and access, it is impossible to sample the entire potential home range of the bats.

With the goal of studying the bats' habitat use of the protected area, we chose radio reception sites that would give us maximum coverage of the Subic Bay Freeport (see map, Fig. 2). The actual study area, however, is not defined by the boundaries of the protected area, but rather it is that area that we effectively sampled (i.e. where signal reception is likely from both of the receivers). This included all of the former base at Subic Bay as well as some parts of the provincial land outside of the protected area's boundaries.

For the broad scale vegetative habitat analysis, we defined three types of undisturbed "natural" forest and two grades of disturbed forest. Undisturbed forest types include: 1) lowland dipterocarp forest, 2) mangrove forest, and 3) strand (or beach) forest. Disturbed forest includes: 4) natural forest moderately disturbed by naval installations (e.g. roads, buildings, trails etc.) and by local residents for forest product extraction and/or low level agricultural use, 5) heavily disturbed forest areas (e.g. residential areas with introduced ornamental and agricultural trees, heavily planted agricultural areas, and/or grassland with a few remaining natural forest trees remaining, esp. along waterways). As described above, we only assessed fixed locations of hanging bats, therefore, vegetative habitat types like large bodies of water, grassland devoid of trees, and residential areas with few trees and many buildings were omitted from the

study area. We measured habitat available to the collared bats (Neu et al. 1974) as the proportion of the entire study area comprised of each general habitat type. Using grids of 300m x 300m (a dimension close to our telemetry error; see below), we assigned a vegetative habitat type to each grid based on the results of a floral inventory conducted by Dalmacio & Fernando (2000), our knowledge of the study area, and vegetative cover information on maps (Maps 7072 I and 7072 II, DENR, National Mapping and Resource Information Agency, Makati City, Philippines). We pooled all locations across individuals to determine the proportion of the bats' locations in a particular habitat type.

The microhabitat analysis focused on riparian areas and known bat trees. Availability of riparian areas included the proportion of the study area within 150 meters of rivers and streams. Bats' use of riparian areas is the proportion of the bat locations within 150 meters of a river or stream.

Bat use of trees focused on eleven tree species that were both known to be used by bats (either fruits and/or flowers eaten or trees used for hanging) based on bat hunter interviews, observation, and fecal analysis (Stier in prep., Mildenstein unpubl. data) and that would have been available for the bats' use during the season when we recorded their locations. These tree species were: *Mangifer altissima* (Anacardiaceae); *Terminalia catappa* (Combretaceae); *Calophyllum inophyllum* (Guttiferae); *Sandoricum koetjape* (Meliaceae); *Parkia roxburghia* (Mimosaceae); *Artocarpus blancoi*, *Ficus variegata*, *Ficus* sp. (Urostigma subgenus) (Moraceae); *Syzygium cumini*, *Syzygium simile* (Myrtaceae); *Nauclea orientalis* (Rubiaceae); (Table 1, from Stier in prep.). All of these species and/or congeners of these species have been recorded in other studies as being used by other species of large fruit bats (see Fujita 1991). Availability of bat trees in the

study area was based on a systematic sample of 79, 20m x 20m plots throughout the forest (Dalmacio & Fernando 2000). We determined the bat use of these tree species from a 20 x 20 m plot centered on the fixed hanging bat locations. Within the plot, we recorded which of the bat tree species were present with a size of at least 15 cm dbh. We also noted whether trees were fruiting and flowering and recorded any signs of large fruit bat activity (fruit ejecta and fecal matter) in or near the plot.

For the broad scale habitat type analysis, we tested for statistical significance using a chi-square goodness of fit test. To meet the requirements of at least one expected observation in each category, and no more than 20% of all categories with less than 5 expectations (Dixon & Massey 1969), we lumped our beach and mangrove categories. These represented the smallest proportion of the study area and occur naturally in small amounts and often near to each other. For significance testing of riparian habitat selection, we used chi-square with Yate's correction. To test the significance of bat tree selection, the Mantel-Haenzel chi-square approximation allowed us to evaluate the difference between the bats use of all the bat trees and the availability of these trees in the forest (Agresti 1984).

Due to our low sample sizes of bat locations across individuals (mean # locations/animal=4.7, min.=1, max.=21), we pooled our observations across animals for habitat selection analysis (White & Garrott 2000). Pooling in this way leads to a loss of among animal variability (Neu et al. 1974) and decreases one's ability to assume independence of observations and availability of all habitats to all individuals (Thomas & Taylor 1990). However, we only considered locations of hanging, not flying, bats for analysis, so successive locations of the same individual represent different locations the

bats chose to land for at least ten minutes, as opposed to flying locations on the way to hanging locations. Also, we recorded individuals' locations on a rotation usually leaving at least an hour between locations of the same bat, and no two successive locations were in the same area. Finally, although flying foxes are known to forage in large groups, we feel confident that our pooled locations are independent as none of our locations were grouped close together in space and time.

RESULTS

Mist netting and capturing

We spent twenty-six nights setting mist nets to capture fruit bats. Many of these nights resulted in failed attempts to capture fruit bats, but success increased as we learned more about the bats' flight habits and capabilities of spotting the nets at night. Our experience in the first site led us to develop a mist-netting site in a flight path to the roost, where we had a success rate of captures on ten out of thirteen nights. We caught all our bats in this site.

We caught and affixed radio collars to a total of thirteen bats, seven of which were of the endemic and endangered species, *Acerodon jubatus*, and six were Philippine Giant Fruit Bats, *Pteropus vampyrus lanensis*. Two of the bats were juveniles, one was an adult male, and the rest were adult females. The list of the captured and collared fruit bats with their weights and forearm lengths can be found in Appendix D.

Radio tracking

From the collaring of the first bat in April, we spent 44 nights in the field recording bat locations. Many of these nights we stayed at the roost recording departure

and arrival times and the directions of departure/arrival of the bats. Four of the 44 nights, we used a vehicle to attempt to track individuals. Two teams climbed to high locations and coordinated simultaneous triangulation on 23 different nights. We also tracked a juvenile on foot for four of the nights.

Our radio tracking efforts resulted in 88 triangulated fixed locations of collared fruit bats during their nighttime feeding forays. Of the total 88 triangulated locations, we selected 47 hanging locations to use in the habitat analysis based on the quality control criteria listed above. These locations are from ten animals (*A. jubatus*: 1 adult male, 5 adult females; *P. vampyrus*: 3 adult and 1 juvenile female; mean # locations/animal=4.7, min.=1, max.=21). In general, the fruit bat fixed locations are spread over a 14,000-hectare area (140 km²) and are found in the Subic Bay National Watershed area. Average distance of the locations from the roost is 5.0 km (N= 47, SE= 0.49 km, min.=0.44 km, max.=12.6 km).

Habitat selection analysis: Use vs. Availability

The 47 locations in the various habitat types were distributed in undisturbed dipterocarp forest (32), disturbed forest (10), beach forest (3), and mangrove forest (2). No bat locations were in residential or grassland areas. The observed use of natural forest types (undisturbed lowland, beach, and mangrove forest) was nearly double that of the expected use based on availability. The use of disturbed forest and residential/agricultural was much less than expected (Fig. 3; $X^2 = 39.99$, $df=3$, $p<0.0001$), with the undisturbed lowland forest, and mangrove/beach forests contributing the most to the chi-square value. The preference of undisturbed forest types over disturbed habitats holds true for each

species individually as well (Fig. 4: *Acerodon jubatus*, Fig. 5: *Pteropus vampyrus*), although in both cases the unpooled data are too few for statistical analysis.

Thirty of the 47 fixed locations were in riparian areas. Use of riparian locations was over four times what is expected based on riparian availability (Fig. 6; $X^2 = 21.57$, $df=1$, $p<0.0001$, with Yate's correction). Again, this preferential use of riparian areas by each species is also evident in the unpooled data (Fig. 7: *Acerodon jubatus*, Fig. 8: *Pteropus vampyrus*).

Bat tree analysis is based on 46 plots; one plot was not visited in the field for security reasons. A large percentage of the plots ($39/46 = 85\%$) had bat trees in them that would have been fruiting, flowering, and otherwise available during the time when we recorded the location (Table 1), and we found bat use of these tree species significantly different when compared to availability ($X^2 = 13.32$, $df=1$, $p=0.0003$).

Effect of telemetry error

The average error in location estimation was 238.0 meters ($SE=53.4$, $N=25$). The average distance from a transmitting collar to the receiver location was 11.9 km ($SE= 0.89$, $N=25$). The tested transmitters were, in most cases, further from the receivers than were our recorded foraging locations of the bats. It is, therefore, likely that the estimated error of 238 meters represents a larger error than what we experienced on the foraging data.

Our estimated average error of 238 meters is not likely to be a problem in our assessment of the vegetative habitat types and availability of bat trees in the bat locations. Whitford (1906) notes that natural forest vegetation in this region changes gradually with large-scale altitudinal gradients; the exceptions are beach vegetation and riparian areas,

which tend to be narrow. These gradients and the topography of the area suggest that natural vegetative change in Subic Bay tends to occur at a much larger scale than the possible error in bat locations.

An error of 238 meters could have led to misidentification of habitat types in five of the 47 bat locations. Three of these locations are beach forest habitat, which is naturally a narrow strip of area between the ocean and the forest. The likelihood of misidentification of any of the locations' habitat types, however, is not great. All five of the locations are predominately surrounded by the same habitat, with a different habitat type representing only a small proportion of the surrounding area.

Since we have defined riparian areas as those within 150 m of a river, it is also conceivable that an error of 238 meters led to an inaccurate count of bat locations in riparian areas. As an extreme example, consider an estimated bat location that falls right on the edge of our designated 150 m riparian zone. An error of 238 m could mean that the actual location of the bat is as much as 388 m from the river. We expanded the measure of available riparian habitat to include the largest possible error. Comparing the bats' actual use of riparian areas (the proportion of the bats locations < 150 m from a river) to this larger measurer of availability, we still found the bats' use to be twice what would be expected ($X^2 = 8.36$, $df=1$, $p=.0038$, with Yate's correction).

DISCUSSION

This study addressed habitat use of flying foxes in a mixed landscape of natural, disturbed, and agriculturally altered forest. At one time flying foxes in the Philippines likely lived surrounded by natural forest. Now, with less than 10% of the country's

original lowland forest cover remaining (compiled using Kummer 1991), their large home ranges cover a mixed matrix of artificial, disturbed, and remnant natural forest at most colony sites. For effective flying fox conservation management, it is important to know how they select habitat in these landscapes.

Not much is known about large flying fox use of native forest compared to use of disturbed areas. Some studies on related species have shown flying foxes to live up to their reputation as orchard raiders (Fleming and Robinson 1987; Loebel and Sanewski 1987; Jamieson 1988), they use both native as well as cultivated trees (Richards 1990; Brooke et al. 2000; more in Pierson and Rainey 1992), and/or they rely on natural forests for roosting and tracking their food sources seasonally (Parry-Jones 1987; Eby 1991; Richards 1990; Spencer et al. 1991; Parry-Jones and Augee 1991; Vardon et al. 2001). Our data suggest that in Subic Bay, Philippines, *Pteropus vampyrus* and *Acerodon jubatus* use both disturbed and non-disturbed areas, but are selecting disproportionately for natural forest areas (lowland dipterocarp, beach, and mangrove).

The data are limited for comparison of the two species, but it appears from our study that *Pteropus vampyrus* and *Acerodon jubatus* are using the forest at Subic Bay differently. This concurs with our general understanding of the two bats. *Pteropus vampyrus* is distributed throughout SE Asia and known in other areas to use agriculture and disturbed forest (Heideman & Heaney 1992; Rickart 1993; Widmann 1996). *Acerodon jubatus*, on the other hand, is a Philippine endemic, that according to interviews and anecdotal observations tends to be in or adjacent to undisturbed natural forest (Heideman & Heaney 1992; Stier, in preparation; Mildenstein and Stier personal observations). While our data indicate both are preferentially selecting undisturbed forest

and riparian areas, it appears that *P. vampyrus* is just using the Subic Bay forest in a transient fashion en route to and from the roost (i.e. roughly at 6:30-8:00 pm on their way out to forage and 5:00-6:30 am on their way back). Only 1 of our 28 locations for adult bats between 8:00 pm and 5:00 am was from a *Pteropus vampyrus*.

Subic Bay is a rare large tract of old growth lowland forest surrounded by a mixed matrix of agriculture, grassland, brush, and disturbed upland forest, with some scattered patches of natural forest. It is, therefore, likely that *Pteropus vampyrus* leaving the Subic Bay forest are foraging in areas much more disturbed than Subic Bay forest. It is curious why they would do this, especially since new studies have shown that agricultural fruits offer less, nutritionally, than natural forest fruits (Nelson et al. 2000).

Other biologists have remarked on this apparent habitat use difference between endemics and non-endemic fruit bats. In American Samoa, the local endemic, *Pteropus samoensis*, is characterized as being in large tracts of native, inaccessible forest, while *P. tonganus* is capable of using both disturbed and undisturbed forest (Pierson and Rainey 1992; Brooke 2001). This same pattern seems to exist with the endemic *Pteropus livingstonii* and the non-endemic *Pteropus seychellensis* in Comoros (Cheke & Dahl 1981).

On a microhabitat scale, we asked whether bats are choosing locations within a habitat type for specific trees in those areas. We found that, of the eleven bat tree species that were probably fruiting and flowering during the time we were tracking bats, all but Pahutan (*Mangifera altissima*) were more frequently in bat locations than in the forest in general (Table 1). As a possible explanation for the unexpectedly low use of Pahutan, we have heard from a bat hunter that Pahutan is eaten by *Pteropus vampyrus* but not by

Acerodon jubatus (Stier, in preparation). Since only a quarter of our bat locations came from *P. vampyrus*, it is likely that our pooled locations underestimate the use of areas with Pahutan by *P. vampyrus*.

Santol (*Sandoricum koetjape*) is a likely example of a microhabitat feature selected by foraging bats within the forest. It shows up in hunter interviews and a feeding ecology study as a bat foraging tree (Widmann 1996; Stier, in preparation), and it was fruiting when we took most of our bat locations. Santol showed up over twice as often in bat plots than in the randomly selected forest inventory plots.

Selection of some bat tree species may be underrepresented by our use versus availability comparison. For example, Tangisang bayawak (*Ficus variegata*) seeds are prominent in the fecal analysis of both species of fruit bats (Stier, in preparation). Our finding that it is 50% more frequent in bat plots than in the forest in general, is made more noteworthy by the fact that Tangisang bayawak, like many other ficus, is dioecious (only females produce the figs that bats eat (Corner 1933)) and it fruits year round non-synchronously with con-specifics. Therefore, only a fraction of the female *Ficus variegata* would have been fruiting at any point when a bat chose a location to hang, yet ficus is still 50% more prevalent in bat location as throughout the forest.

Perhaps the most striking discovery of our research is the bats' apparent, preferential use of riparian areas. This has been noted in Australian large flying fox species with a substantial amount of speculation as to whether bats use riparian areas for navigational purposes (Palmer & Woinarski 1999; Eby personal communication) or because of food availability (McWilliam 1985-1986; Palmer et al. 2000).

It is possible that bats use riparian areas for both foraging and navigation, and our study offers support to both explanations. Many of the fruit trees used by bats in the Philippines are found most commonly along rivers. *Mangifera altissima* (in Filipino: Pahutan), *Dracontomelon edule* (Lamio), *Ficus variegata* (Tangisang bayawak), *Nauclea orientalis* (Bankal), and strangler figs (*Ficus* spp., subgenus *Urostigma*) (Filipino: Balete) have all been observed to be most common along watercourses (respectively by Whitford 1906; Flora Malaysiana 1978; Whitford 1906, Corner 1933, Weiblen et al. 1995; Chudnoff 1984; Williams 1921). Figs in general tend to be more common in riparian areas than uplands (see e.g. Gautier-Hion and Michaloud 1989). In support of the hypothesis that bats use rivers to navigate, it is interesting to look at non-riparian bat locations. Of the 17 bat locations classified as non-riparian, 12 were near major landmarks that could have been useful for navigation to these points: 4 were within 250 meters of a river, 5 were along the beach, and 3 were on the highest mountain peak in the study area. This seems to support bats' use of geographical landmarks for navigational purposes. In any case, all of the locations of bats we recorded in riparian areas were hanging locations, so whether the bats were resting, foraging, mating, or socializing, they are indeed using the trees along the river.

Data limitations and the call for more in-depth study of habitat use

Aebischer et al. (1993) warn that habitat use data for a few individuals in a large population are limited in what can be said about the population in general. Garshelis (2000) makes an important argument that habitat selection without investigation of habitat quality falls short of answering the question of habitat suitability. Morrison (2001)

feel that there are too many studies focusing on general habitat use and more emphasis should be placed on the ultimate factors of habitat selection.

We agree, and recognize the limitations of our data (few individuals compared to population size, mostly females, one season, pooled data) and empathize with the biologists (especially Morrison 2001) who would like to see more microhabitat investigation and links to population dynamics. There is still a long way to go if radio telemetry is to be used on flying foxes to tackle these data hungry habitat questions. In the meantime, general habitat selection studies like this one are the first step toward learning about unstudied species in logistically challenging remote locations. They provide both a first time view of habitat selection, as well as valuable insights to managers and researchers interested in looking deeper into flying fox habitat questions.

Implications for conservation management of the fruit bats

There is no doubt that flying foxes (Fam. *Pteropodidae*, Old World fruit bats) are worthy of current conservation concern. They are important pollinators and seed dispersers in tropical forests and have been justly called “keystones” or strong ecological interactors, especially in Pacific Island ecosystems where there are few, and often *no*, alternate species to fill these roles (Marshall 1985; Fleming 1988; Cox et al. 1991; Rainey et al. 1995; Richards 1995). Over half (54%) of the 173 species in the *Pteropodidae* family are currently on the International Union for Conservation of Natural and Natural Resources (IUCN) list of threatened and endangered species (IUCN 2000), and many others are thought to belong there but for lack of sufficient data (Mickleburgh et al. 1992). Large fruit bats and fruit bats endemic to insular Southeast Asia, in particular, face serious threats and should be considered conservation priorities.

Deforestation and the resulting habitat destruction that threatens most fruit bats have a greater impact on large bats, which in general require more habitat area (Pierson & Rainey 1992; Widmann 1996). In addition, hunters in the Old World tropics prefer large fruit bats, and have taken a substantial toll on population sizes. Although most countries now recognize fruit bat hunting as illegal, hunting still goes on at high levels for local consumption (Mickleburgh et al. 1992; Brooke & Tschapka 2002; Mildenstein and Stier personal observation). Since large bats tend to roost in conspicuous colonies, they have been easily destroyed in large numbers by nearby orchard owners as well as hunters (see Pierson and Rainey 1992). The IUCN list of threatened and endangered species seems to reflect the added pressure on large fruit bats, listing 63 percent of all large fruit bat species as threatened and endangered (fam. Pteropodidae with forearm > 110mm), while only 41% of smaller fruit bat species are on the list (compiled from IUCN 2000; see Appendix A).

When prioritizing fruit bat conservation, it is also important to consider flying foxes in Southeast Asia, especially insular Southeast Asia, including Taiwan, Japan, Indonesia, Borneo, and the Philippines. Half (83/166) the world's flying fox species are found in Southeast Asia, and half (41/83) of these are recognized as threatened (compiled from Mickleburgh 1992; see Appendix A). When endemism is considered, conservation of insular Southeast Asian fruit bats becomes all the more important; 63% (36/57) of the fruit bats endemic to Southeast Asia, but 75% (33/44) of the fruit bats endemic to insular Southeast Asia are threatened (compiled from Mickleburgh et al. 1992; Wildlife Conservation Society of the Philippines 1997; and IUCN 2000).

Several international conservation organizations recognize the endangerment Southeast Asian large flying foxes and are promoting conservation through educational and research projects (e.g. Bat Conservation International, Wildlife Conservation Society, World Wildlife Fund, Lubee Foundation, etc.). Fruit bat conservation efforts are most lacking on a national and local scale. It is commonly asserted that this is due to disinterest, lack of environmental education and awareness, and/or ineffective government and natural resource management (Mickleburgh et al. 1992; Widmann 1996). But, in cases where there is a willing and able management body intact, there is still an absence of effective fruit bat conservation because of the lack of biological background information useful for conservation management. Such was the case where we worked in Subic Bay, Philippines. Since no ecological studies have been done on *Acerodon jubatus* and only one on *Pteropus vampyrus lanensis* (Widmann 1996), which has direct implications to conservation management, managers, until now, knew little about how to protect the bats, beyond just protecting where they roosted. Our research provided the local conservation efforts with ecological information and added to the small body of literature available on Southeast Asian fruit bats.

The Subic Bay large flying foxes need more than Subic Bay's wildlife managers to protect them. Since they are wide ranging animals it will take cooperation between neighboring protected areas and hundreds of landowners to promote their conservation throughout their home range. In addition to roosting in the Subic Bay protected area, the bats forage throughout the forest. As a group they tend to select natural, undisturbed forest over areas with agriculture and other human disturbances. For effective conservation of the bats, management should begin with curbing development in and

along the forested area and monitoring access by people to enforce hunting restrictions and limit forest degradation.

Riparian areas in particular are important to the bats and are also the most threatened by human development. Rivers and river valleys are heavily impacted by upstream development, damming for water reserves, and factory effluents throughout SE Asia (Dudgeon 1999). In Subic Bay, the mouth of every river is developed, and development projects are planned in riparian areas. Protected river corridors should be considered for the Subic Bay protected area management plan as an important step toward wildlife conservation.

Finally, it is important for managers to consider the difference in habitat use between the two species. Unlike the widely distributed *Pteropus vampyrus*, *Acerodon jubatus* is endemic to the Philippines, endangered, and evidence is mounting that they are natural forest obligates. With so little forest left in the Philippines, natural forest endemics, like *Acerodon jubatus* should be a priority for conservation management.

LITERATURE CITED

- Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. *Ecology* 74(5):1313-1325.
- Agresti, A. 1984. Analysis of ordinal categorical data. Wiley series in probability and mathematical statistics. John Wiley and Sons, Inc. New York. 287 pp.
- Augee, M. L., and D. Ford. 1999. Radio-tracking Studies of Grey-headed Flying-foxes, *Pteropus poliocephalus*, from the Gordon Colony, Sydney. Proceedings of the Linnean Society of New South Wales. 121:61-70.
- Bradbury, J. W. 1977. Lek mating behavior in the Hammer-headed bat. *Zeitschrift Tierpsychologie* 63:225-255.
- Brooke, A. P. 2001. Population status and behaviours of the Samoan flying fox (*Pteropus samoensis*) on Tutuila Island, American Samoa. *Journal of Zoology (London)* 254:309-319.
- Brooke, A. P., and M. Tschapka. 2002. Threats from overhunting to the flying fox, *Pteropus tonganus*, (Chiroptera: Pteropodidae) on Niue Island, South Pacific Ocean. *Biological Conservation* 103:343-348.
- Brooke, A.P., C. Solek, and A. Tualaulelei. 2000. Roosting behavior of colonial and solitary flying foxes in American Samoa (Chiroptera: Pteropodidae). *Biotropica* 32(2):338-350.
- Cheke, A. S., and J. F. Dahl. 1981. The status of bats on western Indian Ocean islands, with special reference to *Pteropus*. *Mammalia* 45:205-238.
- Chudnoff, M. 1984. Tropical timbers of the world. USDA Forest Service. Agricultural Handbook No. 607.

- Corner, E. J. H. 1933. A revision of the Malayan species of *Ficus*: *Covellia* and *Neomorphe*. *Malayan Branch Royal Asiatic Society* 11:1-65.
- Cox, P. A., T. Elmqvist, E. D. Pierson, and W. E. Rainey. 1991. Flying foxes as strong interactors in south Pacific island ecosystems: a conservation hypothesis. *Conservation Biology* 5(4): 448-454.
- Dalmacio, M. V., and E. S. Fernando. 2000. Flora Resources Inventory Final Report. The Subic Bay Protected Area Management Plan Project. Subic Bay Metropolitan Authority, Ecology Center. Subic Bay Freeport Zone.
- Dixon, W. J., and F. J. Massey, Jr. 1969. Introduction to statistical analysis. 3rd ed. McGraw-Hill, New York. 638 pp.
- Dudgeon, D. 1999. Tropical Asian Streams. Zoobenthos, Ecology, and Conservation. Hong Kong University Press. 830 pp.
- Eby, P. 1991. Seasonal movements of Grey-headed Flying-foxes, *Pteropus poliocephalus* (Chiroptera: Pteropodidae), from two maternity camps in Northern New South Wales. *Wildlife Research*. 18:547-549.
- Eby, P. 1998. An analysis of diet specialization in frugivorous *Pteropus poliocephalus* (Megachiroptera) in Australian subtropical rainforest. *Australian Journal of Ecology* 23:443-456.
- Fleming, T. H. 1988. The Short-tailed Fruit Bat. University of Chicago Press.
- Fleming, P. J. S., and D. Robinson. 1987. Flying-fox (Chiroptera:Pteropodidae) on the north coast of New South Wales: damage to stonefruit crops and control methods. *Australian Mammalogy* 10(1-2):143-145.
- Flora Malaysiana. 1978. Anacardiaceae. *Flora Malaysiana Volume 8 Series 1*.

- Fujita, M. S. 1991. Flying fox (Chiroptera:Pteropodidae) pollination, seed dispersal, and economic importance: a tabular summary of current knowledge. Resource Publication No. 2. Bat Conservation International.
- Garshelis, D. L. 2000. Delusions in habitat evaluation: measuring use, selection, and importance. Pages 111-164 in Boitani, L. and T. K. Fuller, editors. Research Techniques in Animal Ecology: controversies and consequences. Columbia University Press. New York. 442 pp.
- Gautier-Hion, A., and G. Michaloud. 1989. Are figs always keystone resources for tropical frugivorous vertebrates? A test in Gabon. *Ecology* 70(6):1826-1833.
- Heideman, P. D., and L. R. Heaney. 1989. Population biology and estimates of abundance of fruit bats (Pteropodidae) in Philippine submontane rainforest. *Journal of Zoology (London)* 218:565-586.
- Heideman, P. D., and L. R. Heaney. 1992. In Mickleburgh, S.P., A. M. Hutson, and P. A. Racey, editors. *Old World Fruit Bats: An Action Plan for their conservation*. IUCN Press. Gland, Switzerland.
- Ingle, N. R. 1992. The natural history of bats of Mt. Makiling, Luzon Island, Philippines. *Silliman Journal* 36(1).
- IUCN 2000. 2000 Red list of threatened and endangered species. International Union for Conservation of Nature and National Resources. IUCN Press. Gland, Switzerland.
- Jamieson, G. I. 1988. Fruit losses from flying-foxes in Queensland. *Macroderma* 4:34-42.
- Kummer, D. M. 1991. *Deforestation in the postwar Philippines*. University of Chicago Press. Chicago, Illinois, USA 176pp.

- Kunz, T. H., and E. D. Pierson. 1994. Bats of the World: An Introduction. Pages 1-46 in R. M. Nowak, editor. Walker's Bats of the World. The Johns Hopkins University Press. Baltimore, MD, London. 287 pp.
- Loebel, R., and G. Sanewski. 1987. Flying-foxes (Chiroptera:Pteropodidae) as orchard pests. Australian Mammalogy. 10(1-2):147-150.
- Marimuthu, G., K. E. Rajan, A. J. Koilraj, S. S. Isaac, and J. Balasingh. 1998. Observations on the foraging behavior of a tent roosting megachiropteran bat *Cynopterus sphinx*. Biotropica 30(2):321-324.
- Marshall, A. G. 1985. Old world phytophagous bats (Megachiroptera) and their food plants: a survey. Zoological Journal of the Linnean Society 83:351-369.
- Martin, L., J. H. Kennedy, L. Little, H. C. Luckhoff, G. M. O'Brien, C. S. T. Pow, P. A. Towers, A. K. Waldon, and D. Y. Wang. 1995. The reproductive biology of Australian flying-foxes (genus *Pteropus*). Pages 79-96 in P. M. Racey, and S. M. Swift, editors. Ecology, behaviour, and evolution of bats. Symposia of Zoological Society of London. Volume 67.
- McWilliam, A. N. 1985-1986. The feeding ecology of *Pteropus* in North-Eastern New South Wales, Australia. Myotis 23-24:201-208.
- Mickleburgh, S. P., A. M. Hutson, and P. A. Racey. 1992. Old World fruit bats: An action plan for their conservation. IUCN Press. Gland, Switzerland.
- Mills, L. S., and F. F. Knowlton. 1989. Observer performance in known and blind radio-telemetry accuracy tests. Journal of Wildlife Management 53(2):340-342.
- Morrison, M. L. 2001. A proposed research emphasis to overcome the limits of wildlife-habitat relationship studies. Journal of Wildlife Management 65(4):613-623.

- Mudar, K. M., and M. S. Allen. 1986. A list of bats from northeastern Luzon, Philippines. *Mammalia* 50(2):219-225.
- Nelson, S. L., M. A. Miller, E. J. Heske, and G. C. Fahey, Jr. 2000. Nutritional consequences of a change in diet from native to agricultural fruits for the Samoan fruit bat. *Ecography* 23:393-401.
- Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. *Journal of Wildlife Management* 38:541-545.
- Palmer, C., and J. C. Z. Woinarski. 1999. Seasonal roosts and foraging movements of the black flying fox (*Pteropus alecto*) in the Northern Territory: resource tracking in a landscape mosaic. *Wildlife Research*. 26:823-838.
- Palmer, C., O. Price, and C. Bach. 2000. Foraging ecology of the black flying fox (*Pteropus alecto*) in the seasonal tropics of the Northern Territory, Australia. *Wildlife Research* 27:169-178.
- Parry-Jones, K. 1987. *Pteropus poliocephalus* (Chiroptera:Pteropodidae) in New South Wales. *Australian Mammalogy* 10:81-85.
- Parry-Jones, K., and M. Augee. 1991. Food selection by grey-headed flying-foxes (*Pteropus poliocephalus*) occupying a summer colony site near Gosford, New South Wales. *Wildlife Research* 18:111-124.
- Pierson, E. D., and W. E. Rainey. 1992. The biology of flying foxes of the genus *Pteropus*: a review. Pages 1-17 in D. E. Wilson and G. L. Graham, editors. Pacific Island flying foxes: proceedings of an international conservation conference. U.S. Department of the Interior Biological Report No. 90.

- Rainey, W. E., E. D. Pierson, T. Elmqvist, and P. A. Cox. 1995. The role of flying foxes (Pteropodidae) in oceanic island ecosystems of the Pacific. Pages 47-62 in P. M. Racey and S. M. Swift, editors. Ecology, behaviour and evolution of bats. Symposia of Zoological Society of London. Number 67.
- Reiter, J., and E. Curio. In press. Home range, roost switching, and foraging area in a Philippine fruit bat (*Ptenochirus jagori*). Ecotropica.
- Richards, G. C. 1990. The spectacled flying-fox, *Pteropus conspicillatus* (Chiroptera:Pteropodidae) in northern Queensland. 2. Diet, seed dispersal and feeding ecology. Australian Mammalogy 13:25-32.
- Richards, G. C. 1995. A review of ecological interactions of fruit bats in Australian ecosystems. Pages 167-184 in P. M. Racey and S. M. Swift, editors. Ecology, behaviour and evolution of bats. Symposia of Zoological Society of London. Number 67.
- Rickart, E. A. 1993. Diversity patterns of mammals along elevational and disturbance gradients in the Philippines: Implications for conservation. Asia Life Sciences. 2:251-260.
- Spencer, H. J., C. Palmer, and K. Parry-Jones. 1991. Movements of fruit bats in eastern Australia, determined by using radio-tracking. Wildlife Research 18:463-468.
- Stier, S. C. In preparation. Food habits of the co-roosting golden crowned flying fox (*Acerodon jubatus*) and Philippine giant fruit bat (*Pteropus vampyrus*): implications for conservation and forest restoration. M.S. thesis. University of Montana.

- Thomas, D. L., and E. H. Taylor. 1990. Study designs and tests for comparing resource use and availability. *Journal of Wildlife Management* 54(2):322-330.
- Tidemann, C. R., M. J. Vardon, R. A. Loughland, and P. J. Brocklehurst. 1999. Dry season camps of flying-foxes (*Pteropus* spp.) in Kakadu World Heritage Area, north Australia. *Journal of Zoology (London)* 247:155-163.
- Vardon, M. J., and C. R. Tidemann. 1998. Reproduction, growth and maturity in the Black Flying-fox, *Pteropus alecto*, (Megachiroptera:Pteropodidae). *Australian Journal of Zoology* 46:329-344.
- Vardon, M. J., P. S. Brocklehurst, J. C. Z. Woinarski, R. B. Cunningham, C. F. Donnelly, and C. R. Tidemann. 2001. Seasonal habitat use by flying-foxes, *Pteropus alecto* and *P. scapulatus* (Megachiroptera), in monsoonal Australia. *Journal of Zoology (London)* 253:523-535.
- Walton, R., and B. J. Trowbridge. 2000. The use of radio-tracking in studying the foraging behaviour of the Indian Flying Fox (*Pteropus giganteus*). *Notes from the Mammal Society*. 47:575-579.
- Weiblen, G., B. Flick, and H. Spencer. 1995. Seed set and wasp predation in dioecious *Ficus variegata* from an Australian wet tropical forest. *Biotropica* 27(3): 391-394.
- White, G. C., and R. A. Garrott. 2000. Analysis of wildlife radio-tracking data. Academic Press. San Diego, London. 383 pp.
- Whitford, H. N. 1906. The vegetation of the Lamao Forest Reserve. *Philippine Journal of Science* 1, Supplement 1:373-679.

Whitmore, T. C. 1997. Tropical forest disturbance, disappearance, and species loss.

Pages 3-12 in Laurance, W.F. and R. O. Bierregaard, Jr. editors. Tropical forest remnants: ecology, management, and conservation of fragmented communities.

University of Chicago Press, Chicago.

Widmann, P. 1996. Importance of fruit bats for pollination and seed dispersal in orchards

and forests in Leyte, Philippines. Deutsche Gesellschaft fuer Technische

Zusammenarbeit (GTZ) GmbH, Postfach 5180, D-65726 Eschborn.

Wildlife Conservation Society of the Philippines. 1997. Philippine Red Data Book.

Bookmark, Inc. Makati, Philippines. 240 pp.

Williams, F. 1921. Some observations on Figs in South-Central Luzon, Philippine

Islands. Hawaiian Sugar Planters' Association, Experiment Station. Hawaiian

Planter's Record 25: 202-225.

Winkelmann, J. R., F. J. Bonaccorso, and T. L. Strickler. 2000. Home range of the

southern blossom bat, *Syconycteris australis*, in Papua New Guinea. Journal of

Mammalogy 81(2):408-414.

TABLE 1. Identification, use, and availability of tree species used by bats.

Bat Tree	Local Name	How identified? ¹	Observed use ²	Expected use ³
<i>Parkia roxburghii</i>	Kupang	fecal, obs., hunters	14	7.57
<i>Sandoricum koetjape</i>	Santol	hunters, Widmann 1996	9	4.66
<i>Ficus variegata</i>	Tangisang bayawak	fecal, obs., hunters,	11	7.57
<i>Szygium cumini</i>	Malaruhut	hunters	4	1.16
<i>Nauclea orientalis</i>	Bankal	obs., hunters	2	0.09
<i>Szygium simile</i>	Panglongboien	hunters	2	0.58
<i>Terminalia catappa</i>	Talisay	hunters, Widmann 1996, Fujita 1991	2	0.58
<i>Artocarpus blancoi</i>	Antipolo	hunters	4	1.75
<i>Ficus Urostigma</i> sp.	Balete	fecal, obs., hunters, Utzurum 1984	3	1.16
<i>Callophyllum inophyllum</i>	Bitag	Widmann 1996	2	0.58
<i>Mangifera altissima</i>	Pahunan	hunters	5	5.87

¹ Bat tree identification:

fecal = fecal study (Stier in prep.)

obs. = observed (Stier and/or Mildenstein, personal observation)

hunters= bat hunter interviews (Stier, in preparation, &/or Mildenstein unpublished data)

literature as cited

² Observed use = # bat location plots in which species is present

³ Expected use = # bat location plots in which species is expected, based on proportion of plots in which species is present in floral inventory (Dalmacio & Fernando 2000)

FIGURE 1. Map of the Philippines with primary forests and Subic Bay. Remaining old growth forests in 1992 are shown in black (from Wildlife Conservation Society of the Philippines 1997).

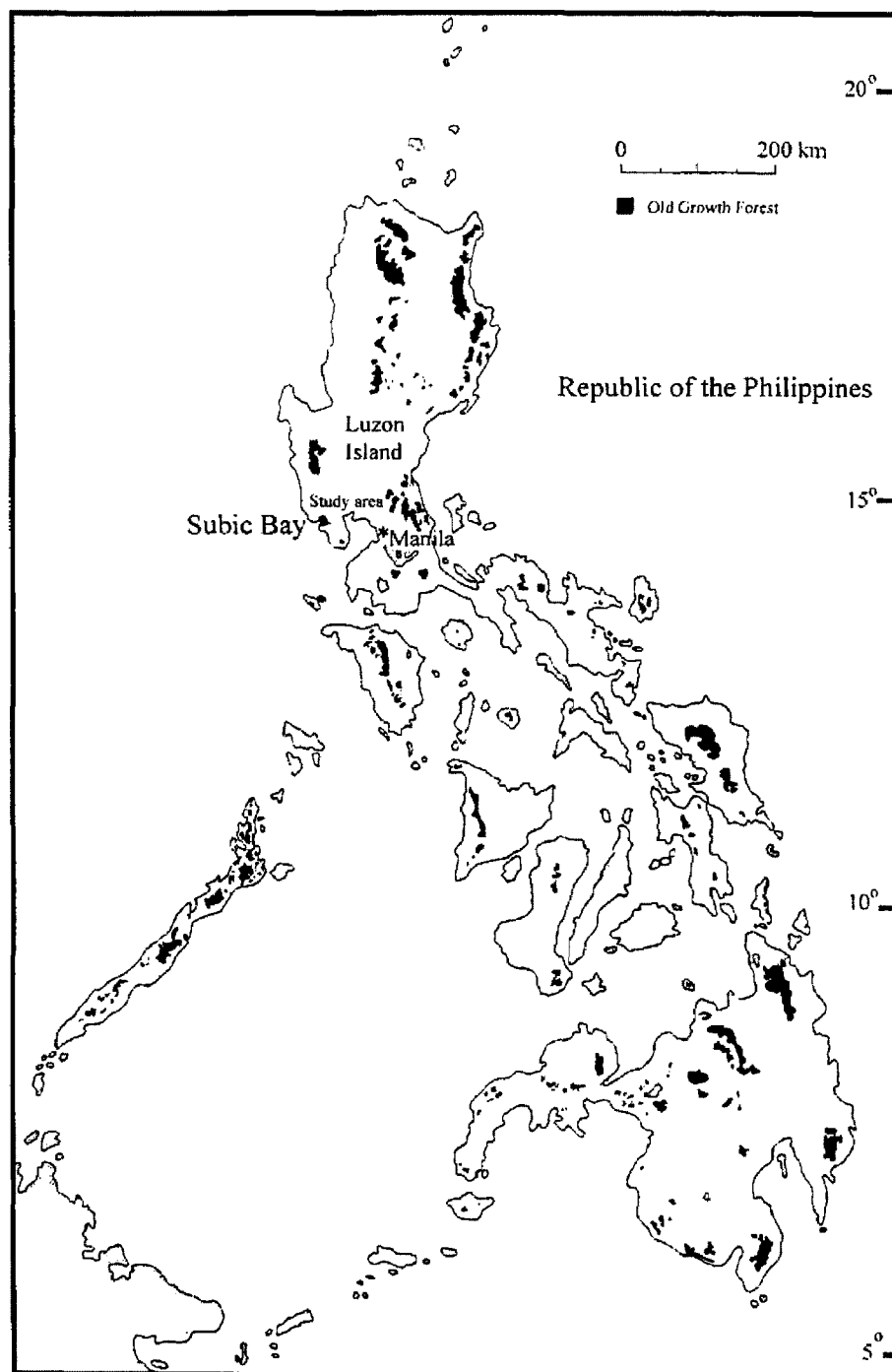


FIGURE 2. Map of the study area with receiver locations and bat locations. Subic Bay protected area boundary is shown in black.

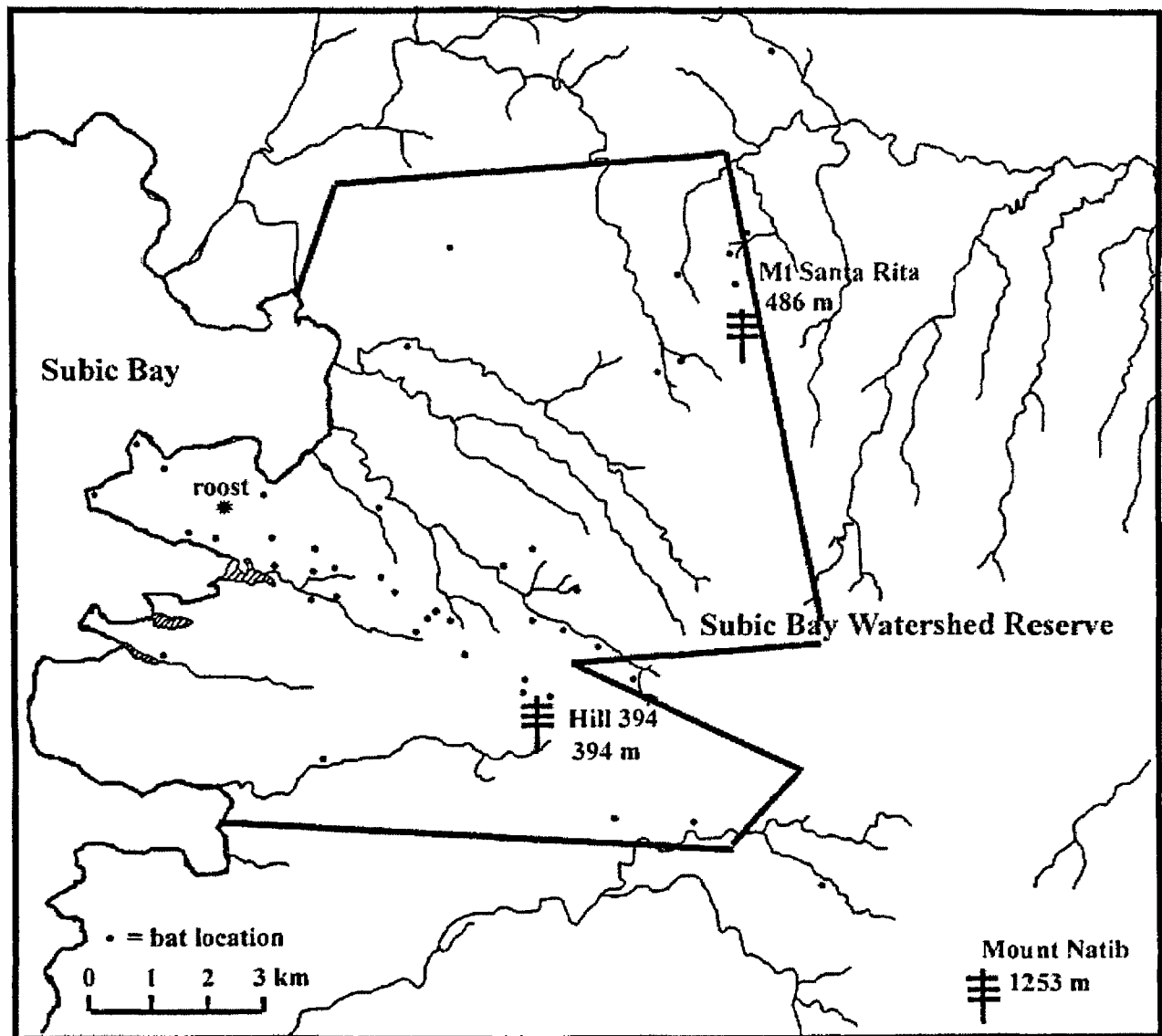


FIGURE 3. Availability and bat use of habitat by vegetation type (pooled data).

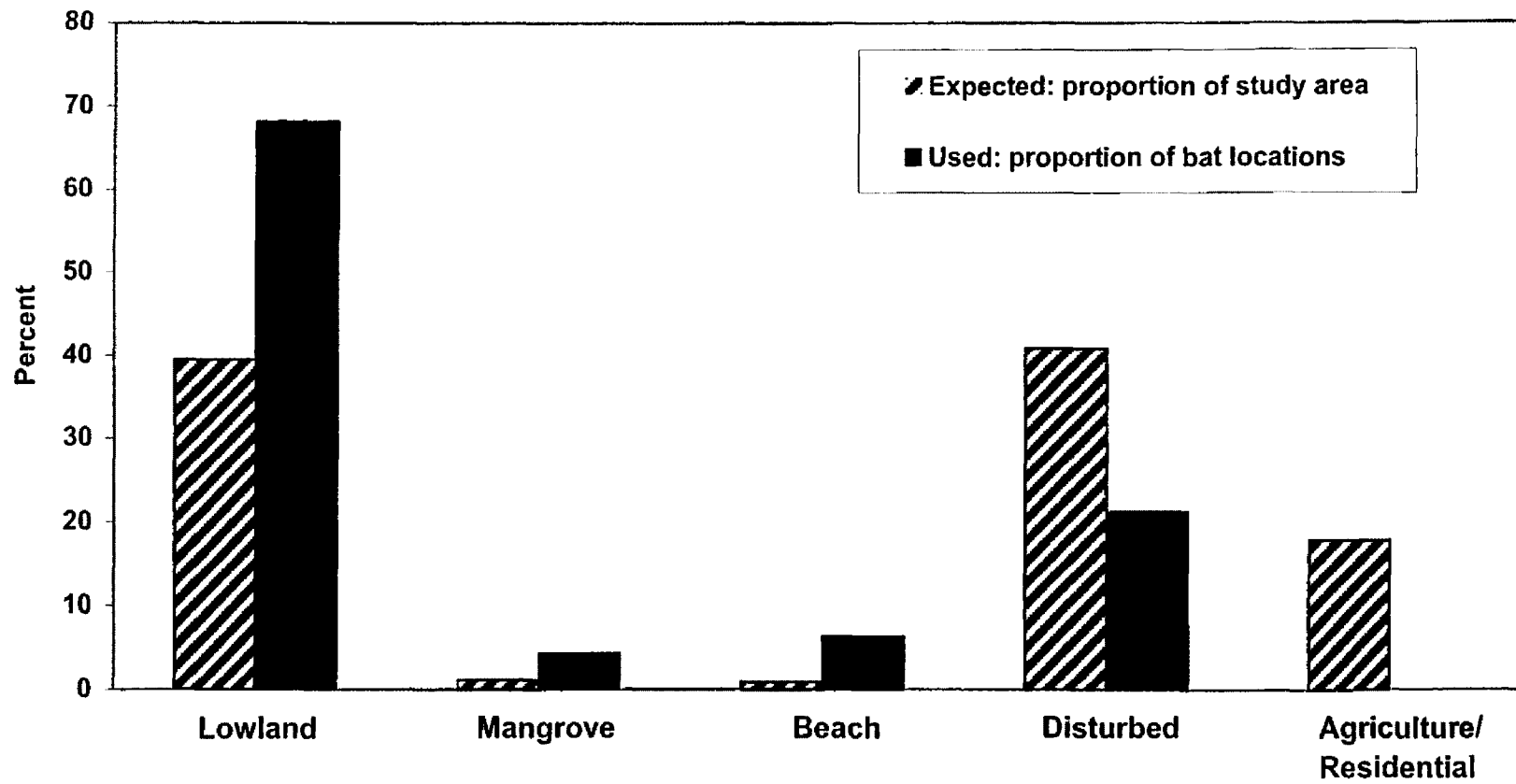


FIGURE 4. *Acerodon jubatus*: availability and bat use of habitat by vegetation type.

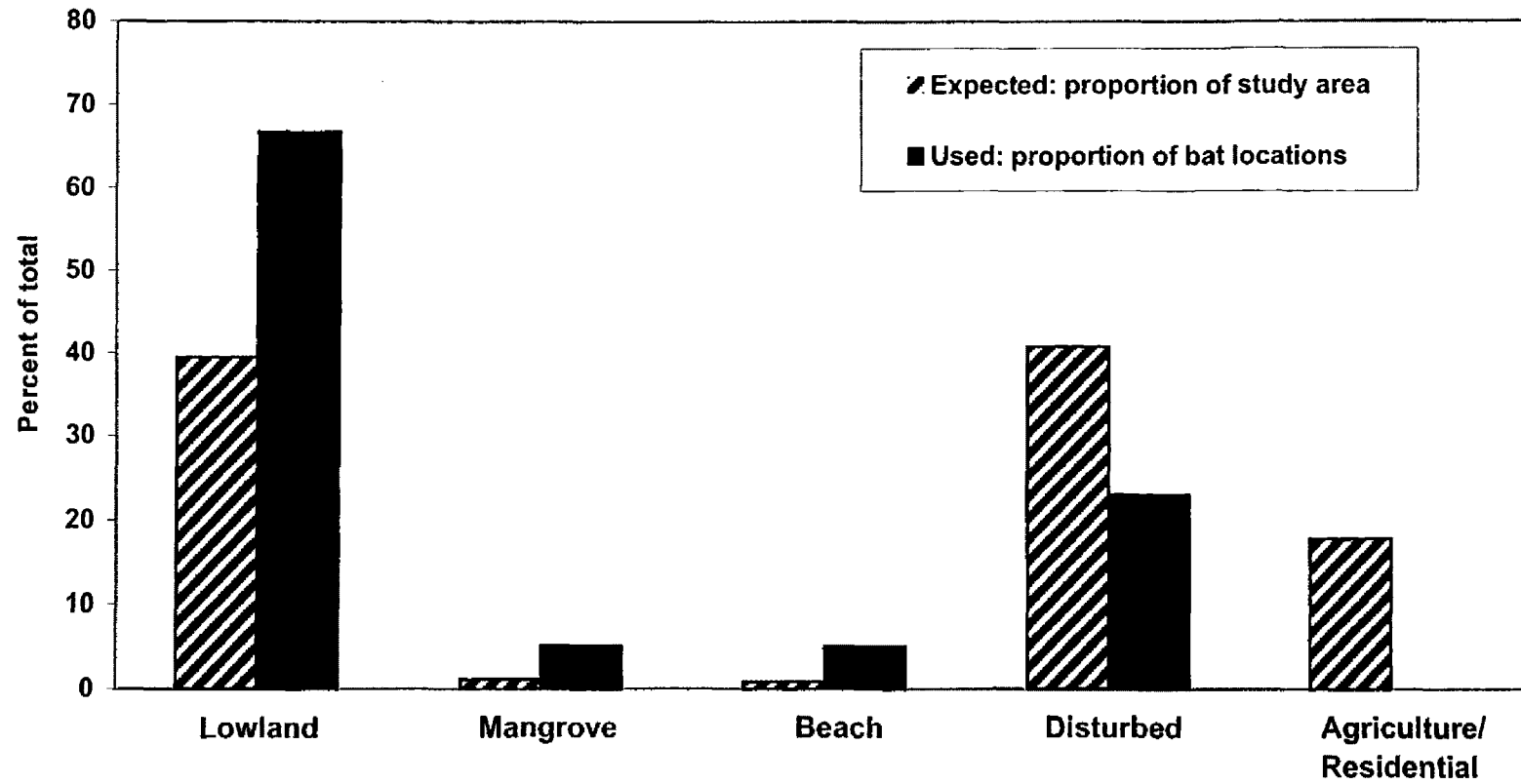


FIGURE 5. *Pteropus vampyrus*: availability and bat use of habitat by vegetation type.

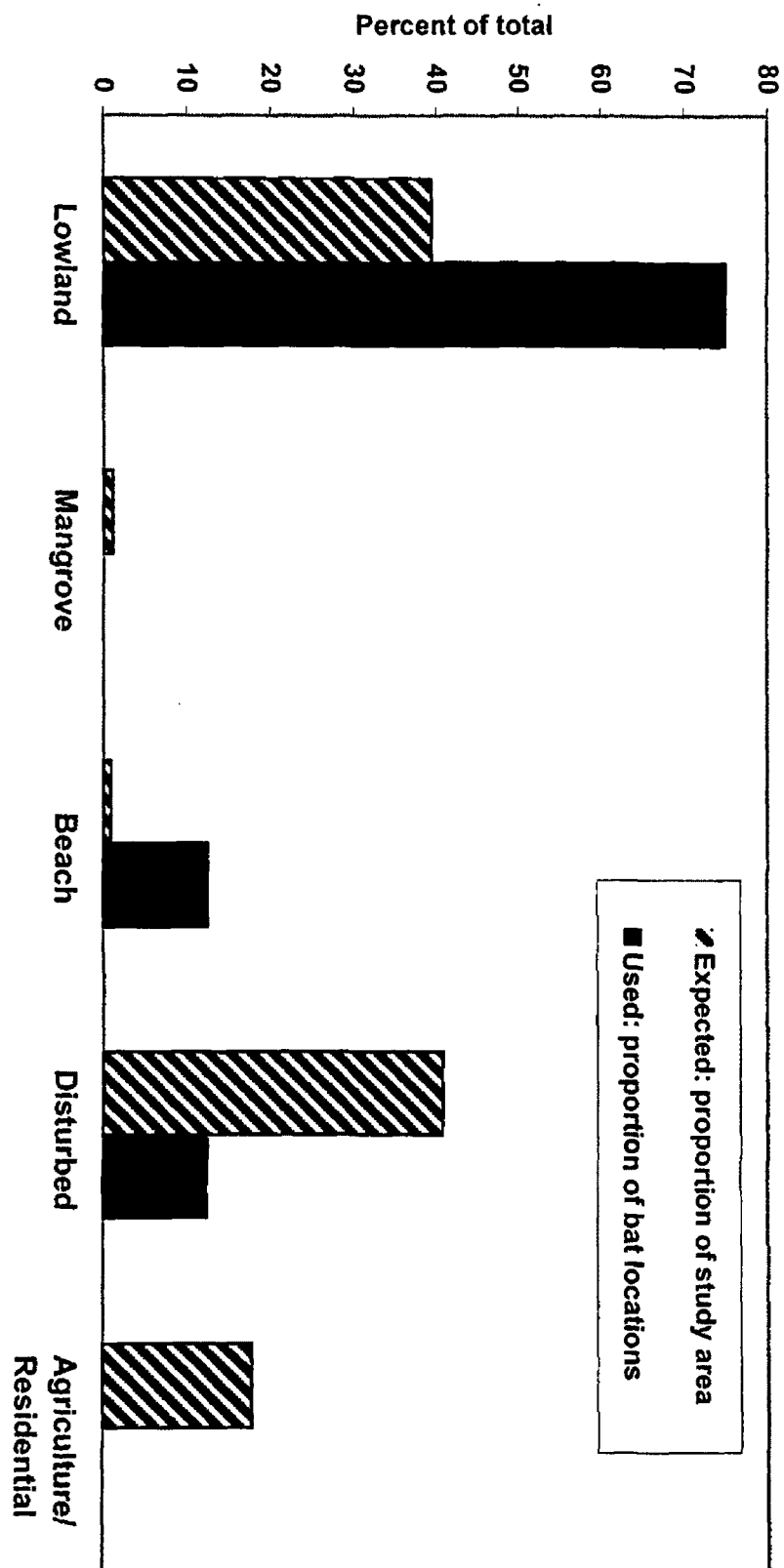


FIGURE 6. Availability and bat use of riparian areas (pooled data).

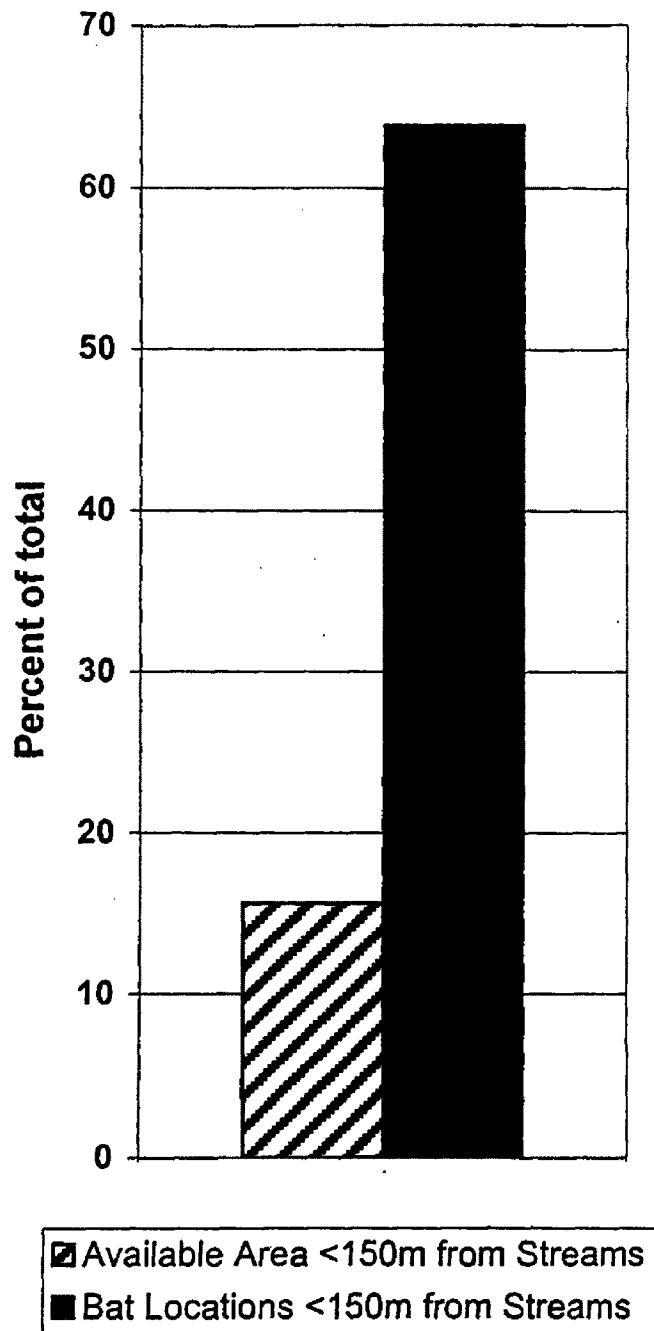


FIGURE 7. Availability and bat use of riparian areas for *Acerodon jubatus*.

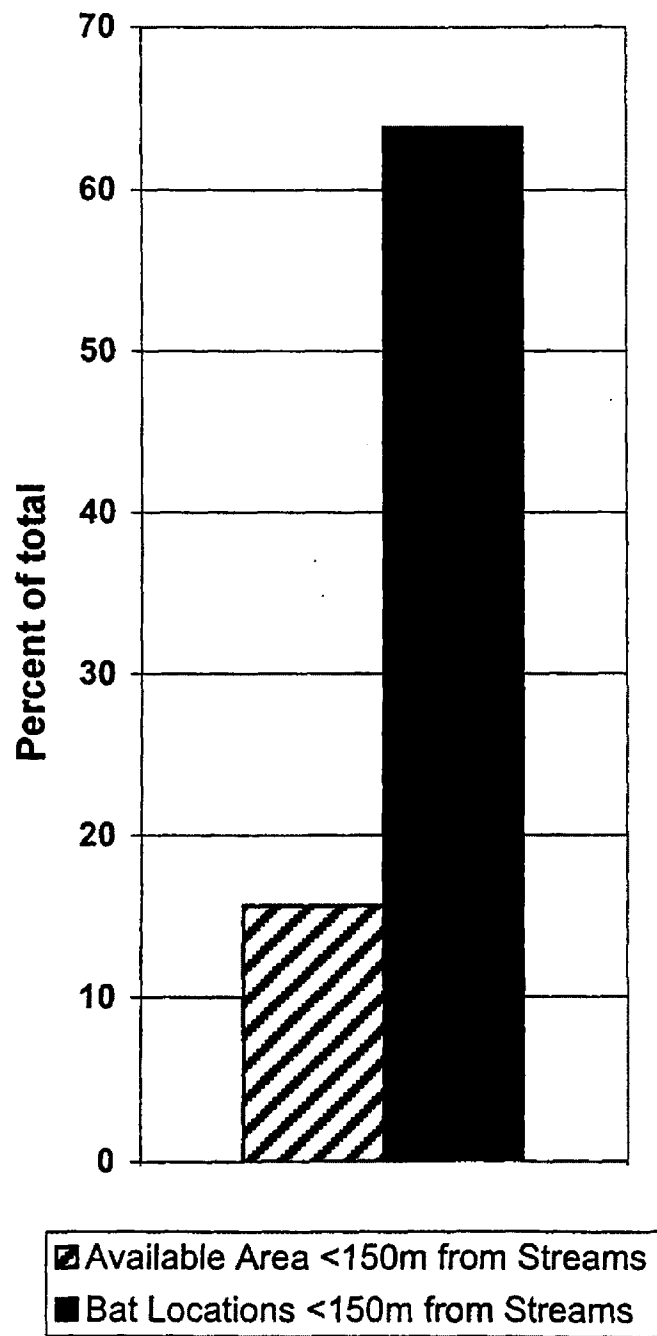
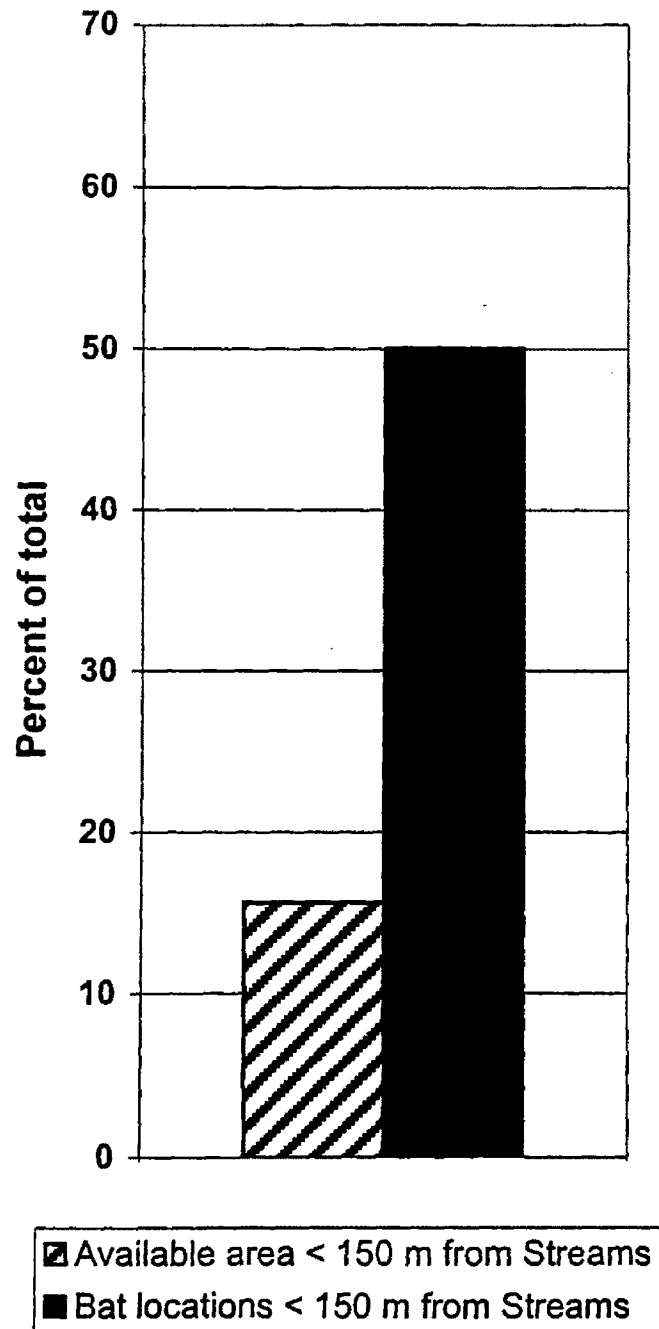


FIGURE 8. Availability and bat use of riparian areas for *Pteropus vampyrus*.



APPENDIX A: Endangerment of Old World fruit bats by size and endemism to Southeast Asia.

ALL OLD WORLD FRUIT BATS

166 Pteropodidae species total
(166 from Wilson and Reeder 1993 +1 *P. loochoensis* – 1 *A. lucifer*)

(161 Mickleburgh et al. 1992, +1 *Pteropus loochoensis*,
+1 *Cynopterus nusenengara*, +1 *Nyctimene certans*,
+1 *Pteralopex pulchra*, +1 *Pteropus aldabrensis*,
+1 *Harpyionycteris celebensis* – 1 *Acerodon jubatus*)

92 Pteropodidae species on IUCN 2000 Red List
(93 Pteropodid species on IUCN Red List – 1 *Acerodon lucifer* = 92)

Percent of all Old World fruit bats considered to be threatened (IUCN 2000)
92/166 = 55%

LARGE BATS

Large flying foxes have forearm range with max.>110mm. Includes genera:
Acerodon, *Aproteles*, *Dobsonia*, *Eidolon*, *Hypsignathus*, *Pteralopex*, *Pteropus*
(from Pierson and Rainey 1992; Kunz and Pierson 1994)

* = forearm range nears 110mm but not over	I = found on islands
ND = no data	LD = limited distribution
R = rare	ext = extinct

On the list		Not on the list	
<i>Acerodon</i>			
<i>celebensis</i>	I	<i>macklotti</i>	I
<i>leucotis</i>	I, SE		
<i>humilis</i>	I		
<i>jubatus</i>	I, SE		
<i>Aproteles</i>			
<i>bulmerae</i>	I, LD		
<i>Hypsignathus</i>			
		<i>monstrosus</i>	

Eidolon

helvum (some on I)
dupreanum

Dobsonia

peronii I
beauforti I, LD
praedatrix I, LD
emersa LD
chapmani I
exoleta I
minor I

pannietensis I
inermis I
moluccensis
viridis I

Pteralopex

anceps I, LD
atrata I, LD
acrodonta I, LD
pulchra I, LD

Pteropus

aldabrensis I
argentatus (assumed) I, LD
brunneus (ext) I, LD
chrysoproctus I,
dasympallus I, LD
faunulus I, ND/LD
*fundatus** I, ND/LD
gilliardi I, ND/LD
howensis I, ND/LD
*insularis** I, LD
leucopterus I
livingstonii I, LD
lochoensis I, LD
mahaganus I, LD
mariannus I, LD
mearnsi I, LD
*molossinus** I, LD
niger I, LD
nitendiensus I, LD
ocularis I, ND
ornatus I
*phaeocephalus** I, LD

admiralitatum I (many)
alecto I
anetianus I (ssp: LD)
caniceps I (ND)
conspicillatus I
giganteus I
griseus I, ssp: ND/LD
hypomelanus I
lombocensis I, ssp: ND/LD
lylei
macrotis
melanopogon I, ssp: ND/LD
melanotus I, ssp: ND/LD
neohibernicus I, ssp: ND/LD
personatus I, ND
poliocephalus
rayneri I, ssp: ND/LD
rufus
scapulatus
seychellensis I
tonganus I (many)
vampyrus I (many)

On the list		Not on the list	
<i>pilosus</i>	(ext.) I	<i>woodfordi</i> *	I, ND
<i>pohlei</i>	I, ND/LD		
<i>pselaphon</i>	I, LD		
<i>pumilus</i>	I		
<i>rodricensis</i>	I, LD		
<i>samoensis</i>	I		
<i>sanctacrucis</i>	I, ND/LD		
<i>speciosus</i>	I		
<i>subniger</i>	I (ext.)		
<i>temmincki</i>	I, ND		
<i>tokudae</i> *	I, (ext.)		
<i>tuberculatus</i>	I, ND/LD		
<i>vetulus</i> *	I, R/LD		
<i>voeltzkowi</i>	LD		

Large fruit bat species/genus totals

# Species On the list		Total # Species
4	<i>Acerodon</i>	5
1	<i>Aproteles</i>	1
7	<i>Dobsonia</i>	11
0	<i>Eidolon</i>	2
0	<i>Hypsignathus</i>	1
4	<i>Pteralopex</i>	4
36	<i>Pteropus</i>	59
total: 52		83

Proportion of all Old World fruit bats, which are large (max. forearm > 110mm)
 $83/166 = 50\%$

Proportion of all large flying foxes (w/max. forearm >110mm) that are threatened
 $52/83 = 63\%$

Small Old World fruit bat species (w/max. forearm length <110mm)
 $166-83 = 83$

Species of small Old World fruit bats that are threatened (on IUCN list)
 $92-52 = 40$

Percentage of small Old World fruit bats that are threatened
 $40/83 = 48\%$

Proportion of threatened (per IUCN 2000) Old World fruit bats that are:
large: $52/92 = 57\%$ small: $40/92 = 43\%$

Kunz, T.H., and E.D. Pierson. 1994. Bats of the world: an introduction. pp. 1-46 in R.M. Nowak, ed. *Walker's bats of the world*. The Johns Hopkins University Press. Baltimore, MD, London. 287 pp.

Pierson, E.D., and W.E. Rainey. 1992. The biology of flying foxes of the genus *Pteropus*: a review. In *Pacific Island flying foxes: proceedings of an international conservation conference*: 1-17. Wilson, D.E. and Graham, G.L. (Eds). U.S. Department of the Interior Biological Report No. 90.

SOUTHEAST ASIAN FRUIT BATS: Endangerment of fruit bats in Southeast Asia
(with special attention to large bats endemic to Southeast Asian islands)

Southeast Asian fruit bats on the IUCN Red List of Threatened Species

<i>Acerodon celebensis</i>	I*
<i>Acerodon humilis</i>	I*
<i>Acerodon jubatus</i>	P*
<i>Acerodon leucotis</i>	P*
<i>Aethalops alecto</i>	B, I, M (SeA*)
<i>Alionycteris paucidentata</i>	P*
<i>Dobsonia beauforti</i>	I*
<i>Dobsonia chapmani</i>	P*
<i>Dobsonia emersa</i>	I*
<i>Dobsonia exoleta</i>	I*
<i>Dobsonia minor</i>	I
<i>Dobsonia peronii</i>	I*
<i>Dyacopterus spadiceus</i>	B, I, M, P (SeA*)
<i>Haplonycteris fischeri</i>	P*
<i>Megaerops kusnotoi</i>	I*
<i>Neopteryx frosti</i>	I*
<i>Nyctimene aello</i>	I
<i>Nyctimene celaeno</i>	I*
<i>Nyctimene certans</i>	I
<i>Nyctimene cyclotis</i>	I*
<i>Nyctimene draconilla</i>	I
<i>Nyctimene minutus</i>	I*
<i>Nyctimene rabori</i>	P*
<i>Otopteropus cartilagonodus</i>	P*
<i>Pteropus argentatus</i>	I*
<i>Pteropus chrysoproctus</i>	I*
<i>Pteropus dasymallus</i>	J, T, P (SeA*)
<i>Pteropus leucopterus</i>	P*
<i>Pteropus loochoensis</i>	J*
<i>Pteropus mearnsi</i>	P*
<i>Pteropus ocularis</i>	I*
<i>Pteropus pohlei</i>	I*
<i>Pteropus pselaphon</i>	J*
<i>Pteropus pumilus</i>	I, P (SeA*)
<i>Pteropus speciosus</i>	I, P (SeA*)
<i>Pteropus temmincki</i>	I
<i>Rousettus bidens</i>	I*
<i>Rousettus spinalatus</i>	I, M (SeA*)
<i>Styloctenium wallacei</i>	I*
<i>Syconycteris carolinae</i>	I*
<i>Thoopterus nigrescens</i>	I, P (SeA*)

Southeast Asian fruit bats NOT on the IUCN Red List

<i>Acerodon macklotti</i>	I*	
<i>Balionycteris maculata</i>	B, I, M, Th	(SeA*)
<i>Chironax melanocephalus</i>	B, I, M, Th	(SeA*)
<i>Cynopterus brachyotis</i>	B, I, M, P, S, Th, V	
<i>Cynopterus horsfeldii</i>	B, I, M, Th	(SeA*)
<i>Cynopterus sphinx</i>	I, M, Th, Bu, Ch	
<i>Cynopterus titthaechilus</i>	I	
<i>Dobsonia moluccense</i>	I	
<i>Dobsonia viridis</i>	I*	
<i>Eonycteris major</i>	B, I, M, P	(SeA*)
<i>Eonycteris spelaea</i>	I, M, P, S, Th, V, Bu, Ch	
<i>Harpyionycteris whiteheadi</i>	I, P	(SeA*)
<i>Macroglossus minimus</i>	B, I, M, P, S, Th, V	
<i>Macroglossus sobrinus</i>	I, M, Th, Bu	(SeA*)
<i>Megaerops ecaudatus</i>	B, I, M, Th, V	(SeA*)
<i>Megaerops niphanae</i>	Th, V	
<i>Megaerops wetmorei</i>	B, M, P	(SeA*)
<i>Nyctimene albiventer</i>	I	
<i>Nyctimene cephalotes</i>	I	
<i>Paranyctimene raptor</i>	I	
<i>Petheor lucasi</i>	B, I, M, S	(SeA*)
<i>Ptenochirus jagorii</i>	P*	
<i>Ptenochirus minor</i>	P*	
<i>Pteropus alecto</i>	I	
<i>Pteropus caniceps</i>	I*	
<i>Pteropus conspicillatus</i>	I	
<i>Pteropus giganteus</i>	Bu, Ch	
<i>Pteropus griseus</i>	I	
<i>Pteropus hypomelanus</i>	C, I, M, P, Th, V, Bu	
<i>Pteropus lombocensis</i>	I*	
<i>Pteropus lylei</i>	C, Th, V	(SeA*)
<i>Pteropus macrotis</i>	I	
<i>Pteropus melanopogon</i>	I*	
<i>Pteropus melanotus</i>	I	
<i>Pteropus neohibernicus</i>	I	
<i>Pteropus personatus</i>	I*	
<i>Pteropus vampyrus</i>	B, I, M, P, S, Th, V, Bu	(SeA* but everywhere!)
<i>Rousettus amplexicaudatus</i>	B, C, I, M, Th, Bu	
<i>Rousettus celebensis</i>	I*	
<i>Rousettus leschenaulti</i>	C, I, L, Th, HK, V, Bu, Ch	
<i>Sphaerias blanfordi</i>	Th, Bu, Ch	
<i>Syconycteris australis</i>	I	

Southeast Asian countries: Brunei (B), Burma (Bu), Japan (J), Malaysia (M),
Vietnam (V), Cambodia (C), Thailand (Th), China (C), Taiwan (T),
Philippines (P), Indonesia (I), Laos (L), Hong Kong (HK), Singapore (S),
Southeast Asia (SeA) *endemic

All Pteropodids **not** listed as threatened and endangered by the IUCN:

total= 42, endemic to SE Asia = 21, endemic to SE Asian islands = 33

Just large bats (genera with max. forearm>110mm)

total= 17, endemic to SE Asia = 7, endemic to SE Asian islands = 6

All Pteropodids listed as threatened and endangered by the IUCN:

total= 41, endemic to SE Asia = 36, endemic to SE Asian islands = 33

Just large bats (genera with max. forearm>110mm)

total= 22, endemic to SE Asia = 20, endemic to SE Asian islands = 20

% Southeast Asian fruit bats listed = 41/83 = 49%

% Fruit bats endemic to Southeast Asia = 36/57 = 63%

% Fruit bats endemic to Southeast Asian islands = 33/44 = 75%

Just large fruit bats:

% large fruit bats in Southeast Asia listed = 22/39 = 56%

% large, endemic to SeA bats listed = 20/27 = 74%

% large, endemic to SeA islands listed = 20/26 = 77%

Compiled from:

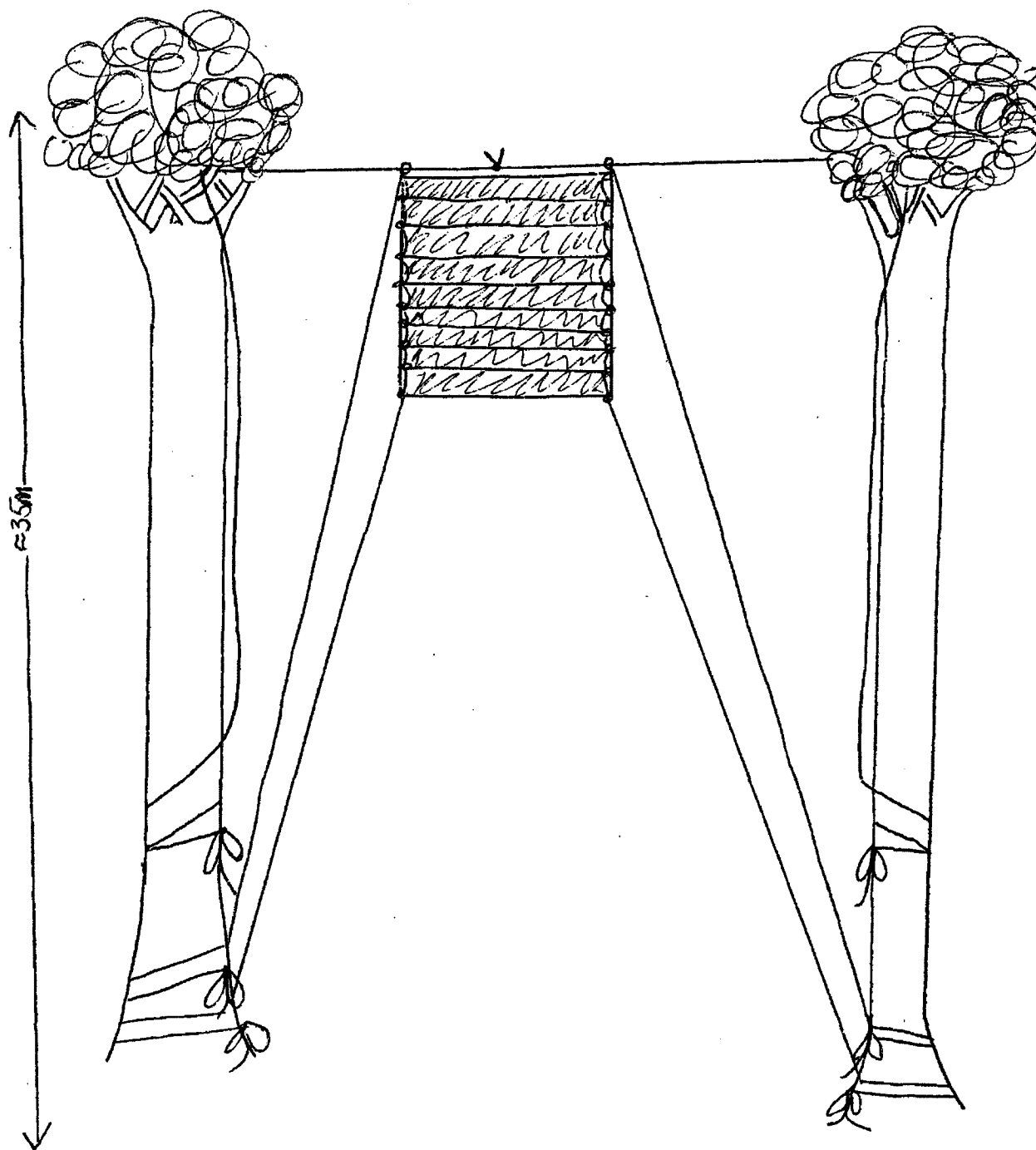
IUCN 2000. 2000 Red list of threatened and endangered species. International Union for
Conservation of Nature and National Resources. IUCN Press. Gland, Switzerland.

IUCN Mammal list is taken from: Wilson, D. E., and D. M. Reeder (editors). 1993.
Mammal species of the world. Smithsonian Institution Press. 1206 pp.

Mickleburgh, S.P., Hutson, A.M., and Racey, P.A. 1992. Old World Fruit Bats: An
Action Plan for their Conservation. IUCN Press. Gland, Switzerland.

Wildlife Conservation Society of the Philippines. 1997. Philippine Red Data Book.
Bookmark, Inc. Makati, Philippines. 240 pp.

APPENDIX B: Diagram of mist net canopy suspension.



Nylon rope

- >4mm twisted nylon is fine for pulling over tree branches (i.e. "top rope")
- for net raising: braided nylon cord is best, because it doesn't twist!
- total length > 8 x height of net

Shower curtain rings

12 per mist net

Brass rings

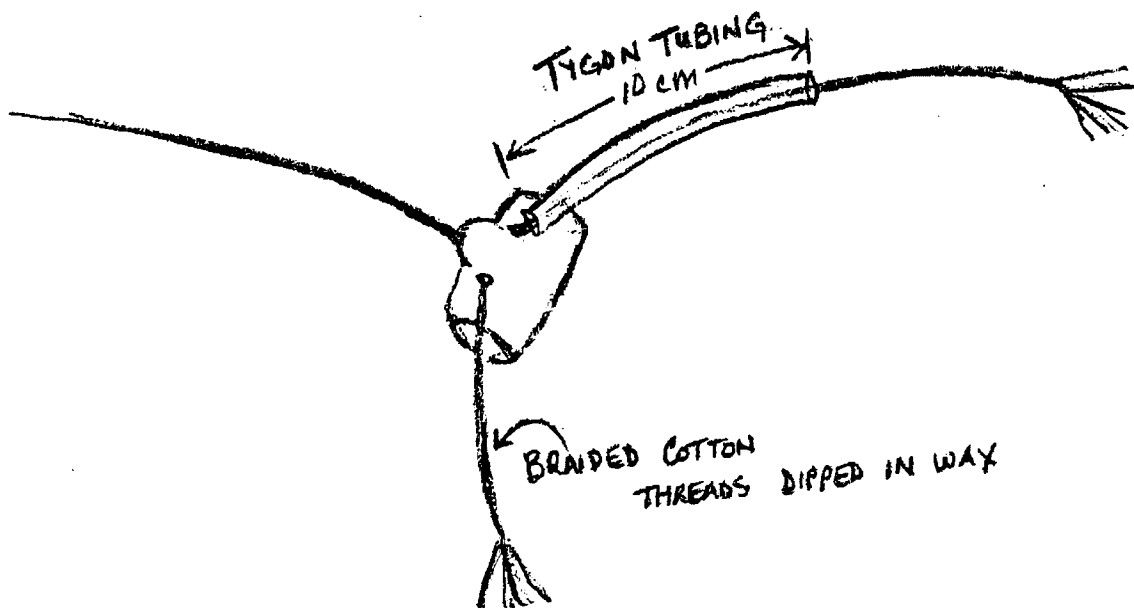
3/4" diameter, 2 pieces to be used as pulleys

APPENDIX C: Short life collar design

Instead of the stainless steel collars that came shipped with the transmitters by the manufacturer (Holohil, Inc. Ontario, Canada), I chose to use a homemade cotton collar to affix the transmitters to the fruit bats. This decision was made for two reasons: 1) the wire collars sent by Holohil were supposed to be attached by a metal crimp, which had sharp edges and seemed dangerous to the bats, and 2) cotton, as an organic material, had the likelihood to stretch a little if necessary and to degrade and fall off eventually. Since the battery life of the transmitters is only 12 months, I wanted to be sure that the collars would not last much longer than the transmitter itself, and thus not punish the fruit bats with the extra weight longer than necessary.

What I found out was favorable to my objectives. Cotton collars lasted over four months, despite the strong tropical sun, a heavy rainy season, and several strong typhoons to which they were subjected. The longest that a bat wore its collar was 24 weeks before it fell off under the roost, and the shortest time before a bat lost its collar was 20 weeks. These results come from the six of the thirteen bats collared, who dropped their collars under the roost.

The implication of this information to future research studies is that it is possible to develop a reliable, short-term collar for transmitters with a limited battery life. This is especially important for radio telemetry studies involving smaller fruit bats, with necessarily lighter transmitters and therefore shorter battery lives. In concern for the individual bats to be captured, I would strongly encourage future researchers to be creative in developing their own collars and avoiding the unnecessarily long-term collars shipped by the manufactures with the transmitters.



APPENDIX D: Table of captured bats

Date	Genus Species	Age Class	Weight	Forearm length
4/17/00	<i>Pteropus vampyrus</i>	female, young adult,	830 g	191.5 mm
4/21/00	<i>Acerodon jubatus</i>	nursing mother	950 g	196 mm
(no collar)	<i>Acerodon jubatus</i>	(pup of above)	100 g	
5/7/00	<i>Pteropus vampyrus</i>	nursing mother	940g w/pup	190 mm
(no collar)	<i>Pteropus vampyrus</i>	(pup of above)		74 mm
5/7/00	<i>Acerodon jubatus</i>	male, adult,	950 g	184 mm
5/10/00	<i>Acerodon jubatus</i>	female, adult	980 g	188 mm
5/10/00	<i>Acerodon jubatus</i>	female, baby	190 g	118 mm (no collar)
5/24/00	<i>Acerodon jubatus</i>	female, adult	850 g	182 mm
5/27/00	<i>Acerodon jubatus</i>	female, adult	880 g	188 mm
5/28/00	<i>Pteropus vampyrus</i>	nursing mother	1095g w/pup	186 mm
(no collar)	<i>Pteropus vampyrus</i>	(pup of above)		127 mm
5/28/00	<i>Pteropus vampyrus</i>	nursing mother	1000g w/pup	185 mm
(no collar)	<i>Pteropus vampyrus</i>	(pup of above)		135 mm
5/29/00	<i>Acerodon jubatus</i>	nursing mother	1100g w/pup	190 mm
	<i>Acerodon jubatus</i>	(pup of above)		110 mm
6/3/00	<i>Pteropus vampyrus</i>	nursing mother	1100g w/pup	197 mm
(no collar)	<i>Pteropus vampyrus</i>	(pup of above)		122 mm
6/12/00	<i>Pteropus vampyrus</i>	female, juvenile	310 g	149 mm
11/5/00	<i>Acerodon jubatus</i>	female, juvenile	650 g	165 mm

CHAPTER 3: Conservation by-products and recommendations to managers

To conclude this thesis, it is important to consider the broad scale conservation implications of the project beyond the ecological research we did on the endangered bats. The items of significance that I will discuss are: 1) The project had an outreach and capacity building aspect, which encouraged our coworkers and the local community to embrace fruit bat conservation. The conservation projects they are now initiating will further the long-term conservation impact of our work. 2) Our long-term research and observations of the bats also led to quite a bit of data, outside the focus of our habitat selection research. I describe, in brief, the other information available as a result of the project. 3) I provide recommendations for conservation management of the large fruit bats. 4) Finally, I discuss future research topics that warrant exploration.

LOCAL OUTREACH AND ENVIRONMENTAL EDUCATION

Our research project was a four-year effort that sought to enhance the conservation of wildlife and fruit bats in many ways beyond the specific research we conducted. Given our goal of promoting conservation, the success of our work is ultimately measured by the actual conservation of the fruit bats, which is difficult to perceive in the short term. But, since the bats' long-term conservation depends on the protected area managers and the local community, the influence of our project on these groups also indicates success in our conservation campaign. Developing the skills of local biologists and protected area staff and their interest in protecting the fruit bats, and educating the local community about conservation, create a context in which fruit bat conservation is likely persistent in the long term. These achievements are described below.

Capacity building of local biologists and protected area staff

We conducted all our research with the help of the local protected area staff, bat hunters, and wildlife biology graduate students from the University of the Philippines. This, of course, was mutually beneficial. The protected area staff, hunters, and students taught us a lot about wildlife and wildlife habitat use as well as the conservation ethic in the Philippines. In turn, we gave them experience and training in field research methods for studying and monitoring endangered wildlife. This exposure had a lasting impact on both sides. We learned to better tailor our research and environmental education efforts to the audiences we hoped to impact, and several of our co-workers got the experience and confidence they needed to initiate their own projects related to wildlife conservation. Two of our coworkers are now focusing on the bats for their academic projects, one adopted our radio telemetry methods to pursue habitat use research of a different species in a different protected area, and one is planning to pursue a master's degree in wildlife biology.

Because of their involvement in our project, local government workers are also much more familiar with bat conservation issues and have initiated projects to promote fruit bat awareness. An informational sign was posted at the bat roost explaining the basic biology and ecology of the bats. Tour guides now have a fruit bat information card that they bring with them on tours to explain the ecology of the bats. Another coworker started an eco-tourism council in the local government and is promoting education and awareness of the Subic Bay forest and wildlife.

Environmental education

Promoting environmental education was another important outreach component of our work. Weekly, when schools came to visit the bat roost, we gave short talks on bat biology and ecology and described our conservation projects. Four universities invited us to lecture to faculty and graduate students to expose them to wildlife research projects going on in the area. Although the project has been over for a year now, I still get email messages from the students and professors I met at these universities, asking for advice on wildlife conservation research projects that they have since begun. Finally, a national television station featured our project on a popular news show. Since November 1999, when this show aired, the public awareness and interest in these bats has grown overwhelmingly. This kind of exposure gave the fruit bats a boost in popularity and created an atmosphere in which our scientific research became meaningful to local protected area managers.

OTHER DATA AVAILABLE

Radio telemetry at the roost

In addition to fixed locations of the bats during their nighttime flights, our radio tracking efforts have produced several nights of information on departure and arrival times from/to the roost, location fidelity within the roost, and roost usage observations. Our findings, in general, are:

- Most bats leave the roost between 5:30 pm and 7 pm. The departure time seemed to change with the time of sunset; November to January departures were around 5:30 and by May and July departures were around 6:30.

- Bats return to the roost between 3:30 am and 6:00 am, and again, this varied with the time of the sunrise.
- Many bats were tracked in the forests near to the roost all night long.
- Mating behavior occurs at the roost between the last week of October and the third week of December, with the peak of activity in November.
- Pups are born to both species between the middle of April and the middle of May.
- Mother bats with very small pups leave the roost to forage as late as 11 pm and tend to stay near to the roost during foraging.
- Nursery trees have been observed at night in and around the roost.
- Many bats (especially *Pteropus vampyrus*) disappear from radio coverage by the middle of the night, suggesting they are using areas outside the SBMA Protected Area.
- Individual collared bats seem to be returning to the same area within the roost every day. I intend to discuss these data in detail in a future publication.
- Bats are sensitive to disturbance at the roost, especially to loud noises and to people and dogs going under the roost.
- Other than people, there are few predators of roosting bats. We observed crows flying at female bats with pups, and some people who worked near the roost brought us a bat that they said was knocked to the ground and killed by crows. We also heard of pythons climbing the roost trees and occasionally killing bats, but we never saw this ourselves.
- We frequently observed fruit bats flying low above the ocean and dipping their hind feet and torso into the water during flight. This occurs on the bats' way out and back

from foraging and is presumably for the acquisition of salt and minerals. Sam Stier's thesis discusses this behavior in depth.

Observations/hunter interviews

Personal observations and interviews with bat hunters and local naturalists not only provided supplementary information on fruit bat habitat use, but also helped me in designing my radio tracking schedule to ensure fruit bat detection. From our personal observations and interviews, we are sure that the fruit bats are traveling well outside the Subic Bay Protected Area at night, and that our lack of radio signal for some bats, therefore, is likely a result of them being outside the radio coverage area as opposed to undetectable for other reasons. We also know from several hunters that the fruit bats are regularly using riparian areas for foraging. This is where hunters choose to hunt, because these areas have the greatest likelihood of fruit bat visitation. Other observations and information derived from bat hunter interviews can be found in Sam Stier's thesis.

RECOMMENDATIONS FOR BAT CONSERVATION MANAGEMENT AT SUBIC BAY

We have several specific suggestions to offer the local protected area management offices for the effective conservation of these fruit bats. Recommendations for protective management at the roost is aimed at the Subic Bay Metropolitan Authority (SBMA) Ecology Center, which is the management office in charge of the Subic Bay forest where the bats roost. Foraging protection suggestions apply to the protected area managers of Subic Bay and the surrounding natural areas, including Bataan National

Park, Zambales Department of Environment and Natural Resources, and managers in charge of Balakibok forests, Mt. Redondo forests, and the Mariveles protected area.

- Protected area offices of SBMA, Bataan (Natib and Mariveles), and Zambales, should collaborate in developing conservation strategies, since the fruit bats use all of these areas for foraging.
- SBMA should make special arrangements for 24-hour protection at the bat roost area. Roost protection should include prohibition of loud noises near the roost and the intrusion by people and pets. Tourists should be monitored to prohibit clapping, rock throwing, and other disturbances intended to make bats fly for picture taking.
- Managers should keep the area free of garbage, since this brings in crows, which have been known to disturb and occasionally kill the bats.
- SBMA and neighboring protected areas should strive to establish workable hunting regulation programs and enforcement. Bat hunters are ubiquitous throughout all these protected areas despite laws against hunting.
- SBMA, in particular, with its interest in the fruit bats as a tourist attraction, should develop and enforce a hunting ban throughout SBMA. At present many SBMA employees are said to be hunters.
- Undisturbed natural forest should be protected from future disturbance, since we found that bats were using undisturbed forest far more than disturbed forest.
- Riparian areas should be protected from disturbance as a large number of the fruit bat locations were found in close proximity to watercourses.

- The bay areas near the bat roost should be protected from pollution and human disturbance, since these are important for the bats' acquisition of salts and minerals.

FUTURE RESEARCH NEEDS

This study represents a first attempt at investigation of the habitat selection of large flying foxes through systematic sampling their locations remotely from the ground. From my experience in conducting this habitat use study, I have learned a lot about the large flying foxes have developed ideas for future research projects. Here are some suggestions, which I believe will be important to the conservation of the flying foxes in Subic Bay.

Home range There have been no home range assessments of large flying foxes, mostly due to their long range movements. Research addressing where the bats are going outside the study area would provide important home range information to management and encourage cooperation between the many protected area management offices in charge of the forests that the bats are visiting. Due to the potentially long range these bats may be flying and the volcanic topography of the area, aerial tracking using radio telemetry may be the only way to accomplish sampling for home range estimation.

Seasonal and individual habitat use It would also be interesting to know the bats' seasonal use of the protected area, and how habitat use differs between individuals, species, age classes, and sexes at different times of the year. Seasonal habitat use information could help management better target their flying fox protection efforts.

Microhabitat use and phenology of bat trees Another important approach is to pay attention to the microhabitat features bats are selecting within broad vegetative habitat types. For example, some of the endemic *Acerodon jubatus* bat locations in this study were in a mango area/disturbed forest at a time when no mangos were fruiting. This area is a riparian area along which we observed several very big fig trees known by hunters to be favorites of *Acerodon jubatus* in particular. So, while they were technically foraging in a disturbed area with agriculture, it is very likely they were using natural forest trees left over in the area. Managers could better use microhabitat features to develop a habitat suitability model for the bats.

Population biology and the impact of hunters We know that fruit bats in Subic Bay are heavily hunted, but this has not been quantified, largely due to hunters being wary of divulging their bat kills. It is difficult to perceive population changes in a colony the size of Subic Bay's, and it is possible this population is declining, although undetected. An important, low-budget, and simple study, would assess hunting pressure on the Subic Bay flying fox population. Hunters could be interviewed to quantify an estimate of total mortality due to hunting in the nine or so communities near to fruit bat foraging areas. This pressure could be compared to estimates of population growth, obtained from observational surveys at the roost during May, June, and July when mothers are carrying babies. While there are many other sources of mortality, it is likely that comparing number of bats killed by hunters to births could reveal evidence of over-hunting and make a compelling argument for regulation.

Acknowledgments

Without strong roots, a tree cannot venture to its outer limits. First, and foremost, I thank my family and friends for all their love and support while I was overseas. I am especially grateful to my parents, Linda and Roger Mildenstein, who convinced me when I was young that I could do anything and, therefore, are responsible for much of the impossible things I attempted during my fieldwork. I cannot thank Sam Stier enough for his love and support. From project design and finding funding all the way through reading and re-reading drafts of this thesis, Sam has made this project be the best it can be. In encouraging me, he aptly invented the phrase: "If it was easy, everyone would have done it by now", which I will never forget.

I would like to express heartfelt thanks to Wildlife Conservation Society, Bat Conservation International, Ford Motors Company-Philippines, World Wildlife Fund-U.S. and Philippines, Subic Bay Metropolitan Authority Ecology Center, Bataan Natural Park, United States Embassy Club Fund, and U.S. Peace Corps for their financial and logistical support throughout this study. Thank you to Peace Corps-Philippines' Julian Tongson, who offered invaluable advice and improved the conservation value of my work 100-fold, and to Lani Berino, and Eloi Gonzales who were my home away from home. I thank L. Scott Mills, Stephen Siebert, Kerry Foresman, Danny Balete, Larry Heaney, Anne Brooke, Peggy Eby, Jochen Reiter, Edwin Manalansan, Doug Reagan, Carlo Custodio, and Jon Graham who proffered their expertise and important advice for the fieldwork methodology, data analysis, and writing of this thesis. My gratitude also

to Hannah Fairbank and to Nonoy Morilao and his friend Pito for the pictures they contributed.

Finally a high-5 thanks a lot to all the people who sweated long, late nights with us in the field braving bamboo vipers, king cobras, leaches, red ants, and malaria. You made the project not only possible, but also more fun! I especially recognize Sam Stier, C.E. Nuevo-Diego, Danny Balete, Joel Sarmiento, Toto Mansanita, Mayie Saulog, Glen Flores, Pat Malabrigo Jr., Edu Breganza, Enrico Breganza, Excel Reyes, Ramil Saquedra, Rolly Urriza, Leo Lapie, Nicky Icarangal, Ernesto Bautista, Scott Mills (and his sling shot capability), Anne Brooke, Jake Esselstyn, Jochen Reiter, Max Stier, Salvador Dimain, Mang Juli and Manuelito and all the SBMA Forest Rangers; Sonny Dela Cruz, Councilman Benjamin, Chairman Abraham, Barangay Kapitan Bonifacio, and the Aetas of Pastolan.